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# C2 Agility: Related Hypotheses and Experimental Findings

David S. Alberts

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# C2 Agility: Related Hypotheses and Experimental Findings

David S. Alberts

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# C2 Agility:
# Related Hypotheses and Experimental Findings

a tutorial presented at

83rd Military Operations Research Society (MORS) Symposium

June 2015


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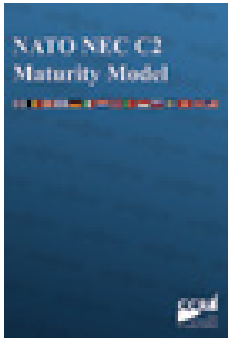
# Agenda

- C2 Agility
- Hypotheses
- Experiments and Results
- Next Steps

# Conceptual Foundation

- C2 Approach Space

  Understanding Command and Control (2006)

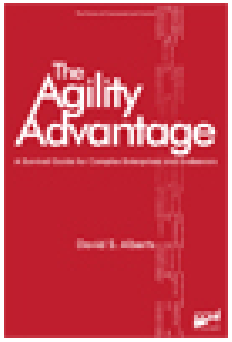



- C2 Maturity Levels

  NATO NEC C2 Maturity Model (2010)

- Agile C2

  The Agility Advantage (2011)




- C2 Agility Experimentation

  NATO SAS-085 (2013)

SAS 085
C2 AGILITY AND REQUISITE MATURITY

This tutorial is based upon the above publications and related presentations

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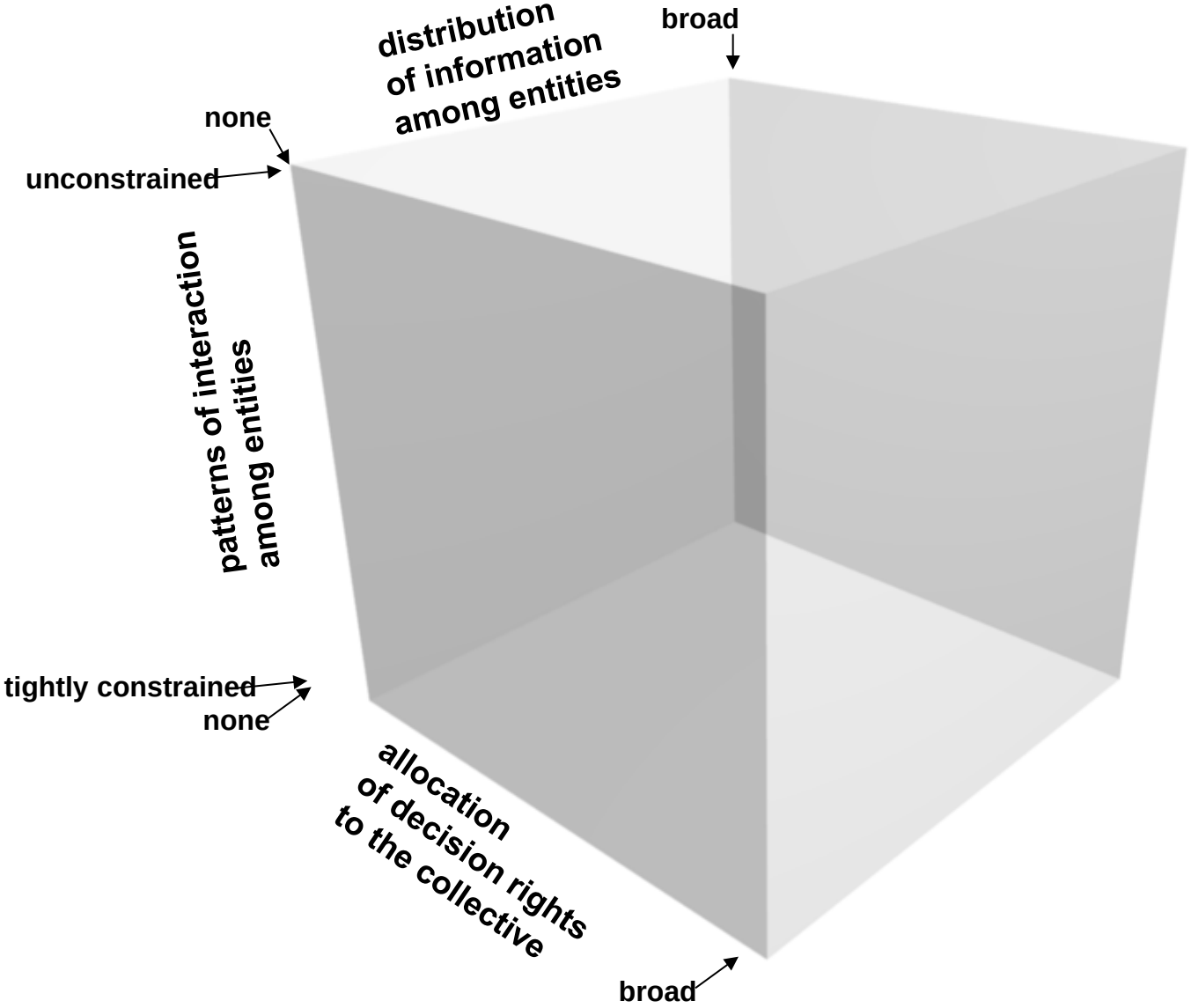
# C2 Approach Space

- There are a great many possible approaches to accomplishing the functions that we associate with Command and Control.

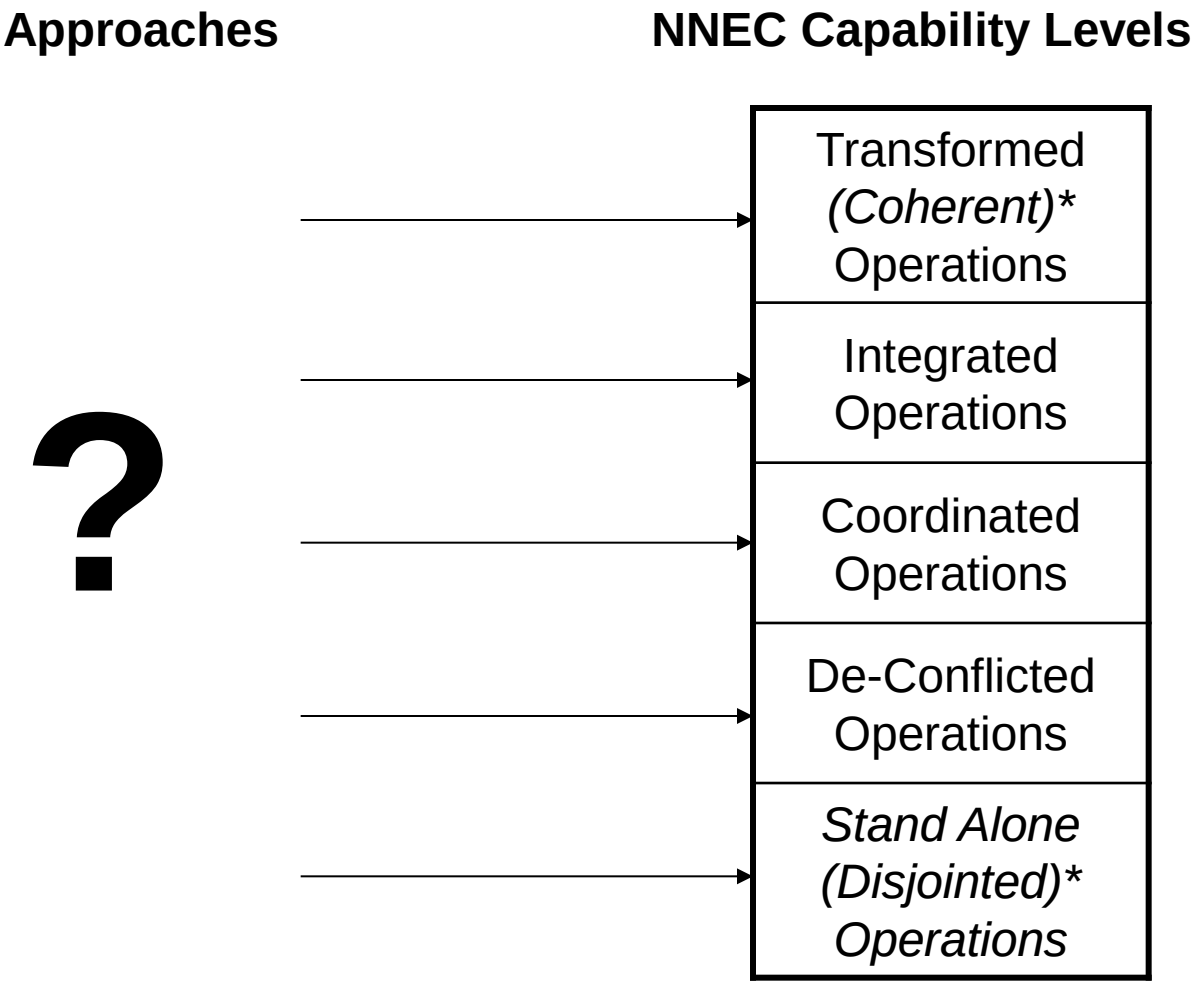
- Developing the "option space" for Command and Control requires that major differences between possible approaches are identified.
    - Centralized v. Decentralized
    - Fixed Vertical Stovepipes v. Dynamic Task Organized
    - Limited information dissemination (need to know) v. broad dissemination (need to share)

- These difference are reflected in the dimensions of the C2 Approach Space (options available)
    - Allocation of Decision Rights (within an entity or to the collective)
    - Patterns of Interaction
    - Distribution of Information

# C2 Approach Space



# C2 Approach → NNEC Maturity




* The NNEC Feasibility Study used the terms *Coherent* and *Disjointed* rather than Transformed and Stand Alone

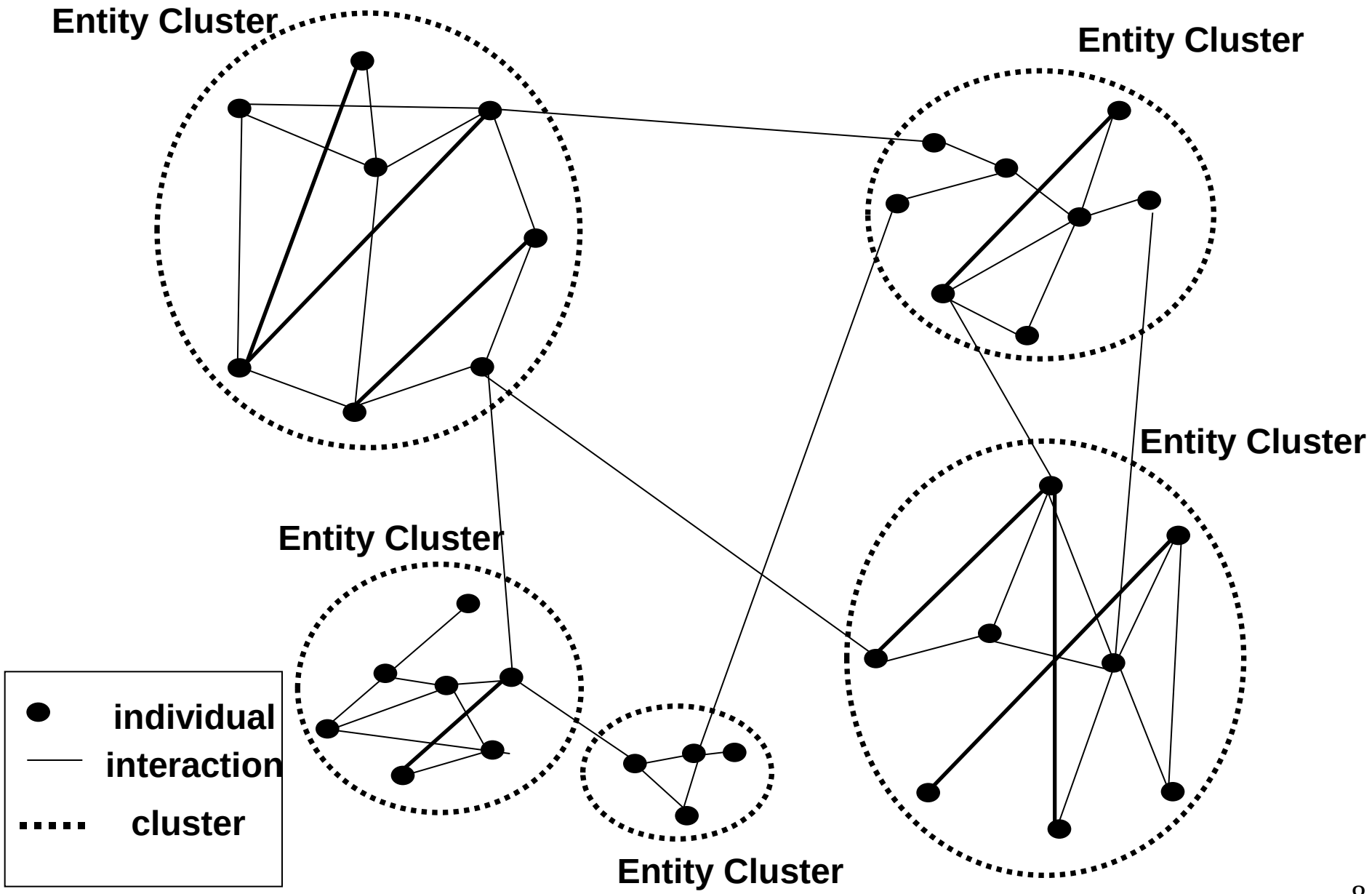
# NATO NEC C2 Approaches

(context is a collection of civil-military entities)

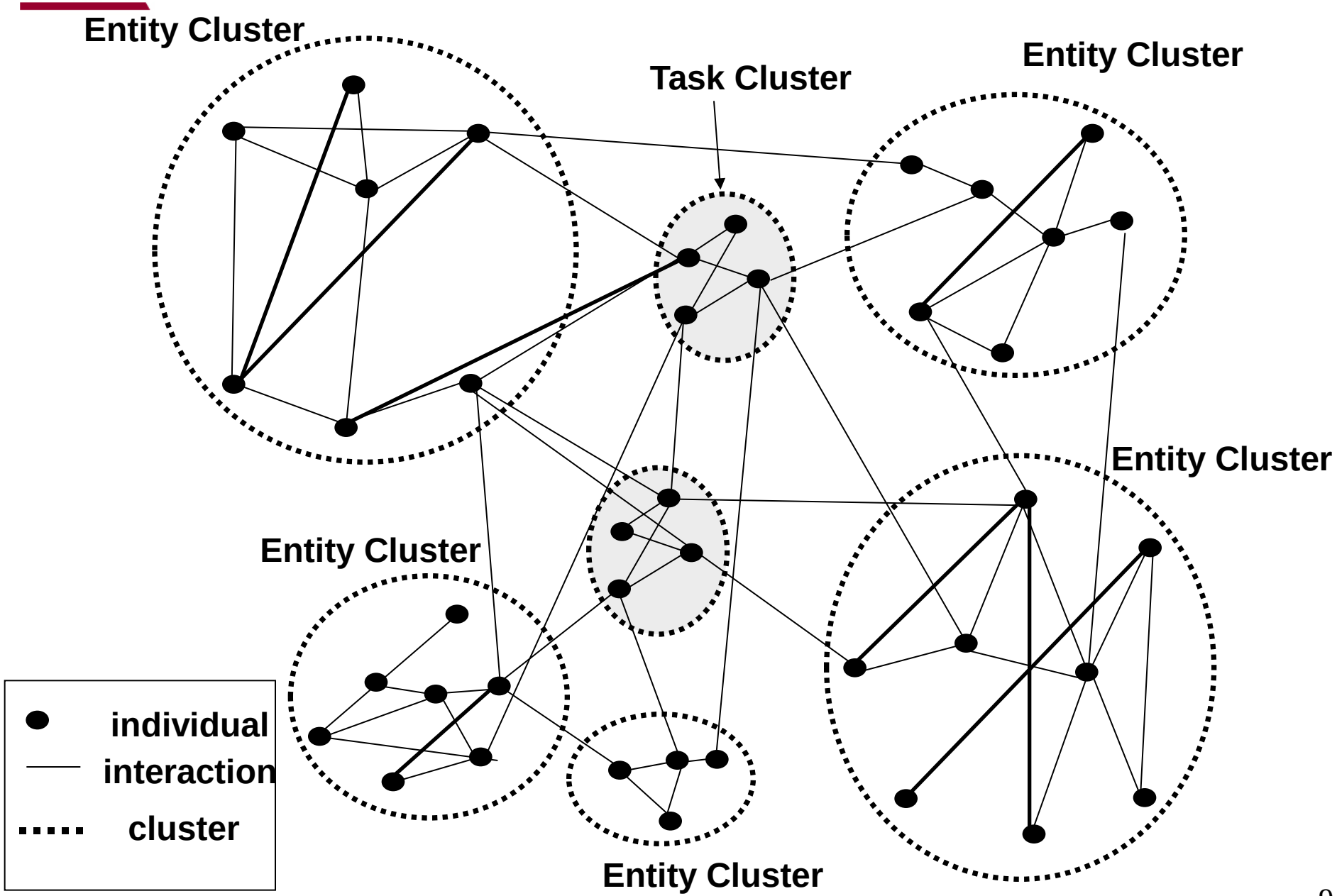
| C2 Approach | Allocation of Decision Rights *to the Collective* | Patterns of Interaction Among Participating Entities | Distribution of Information |
|---|---|---|---|
| **Edge C2** | Not Explicit, Self- Allocated (Emergent, Tailored, and Dynamic) | Unlimited<br>As Required | All Available<br>and Relevant Information<br>Accessible |
| **Collaborative C2** | Collaborative Process<br>and Shared Plan | Significant<br>Broad | Additional Information<br>Across Collaborative<br>Areas/Functions |
| **Coordinated C2** | Coordination Process<br>and Linked Plans | Limited and Focused | Additional Information<br>About Coordinated<br>Areas/Functions |
| **De-Conflicted C2** | Establish Constraints | Very Limited<br>Sharply Focused | Additional Information<br>About Constraints<br>and Seams |
| **Conflicted C2** | None | None | Organic Information |

**Source: NATO SAS-065**

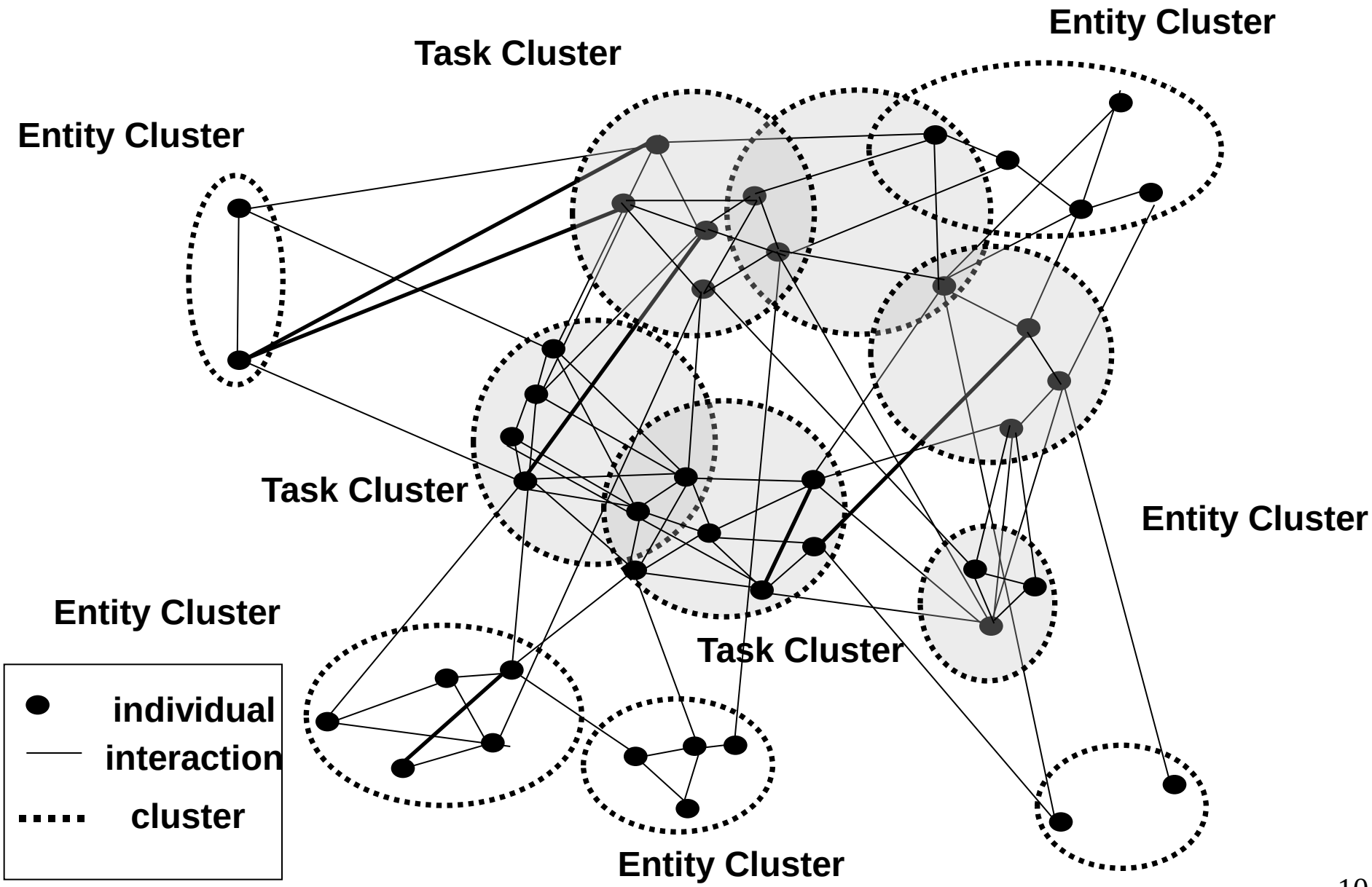
# Patterns of Interactions: De-conflicted C2



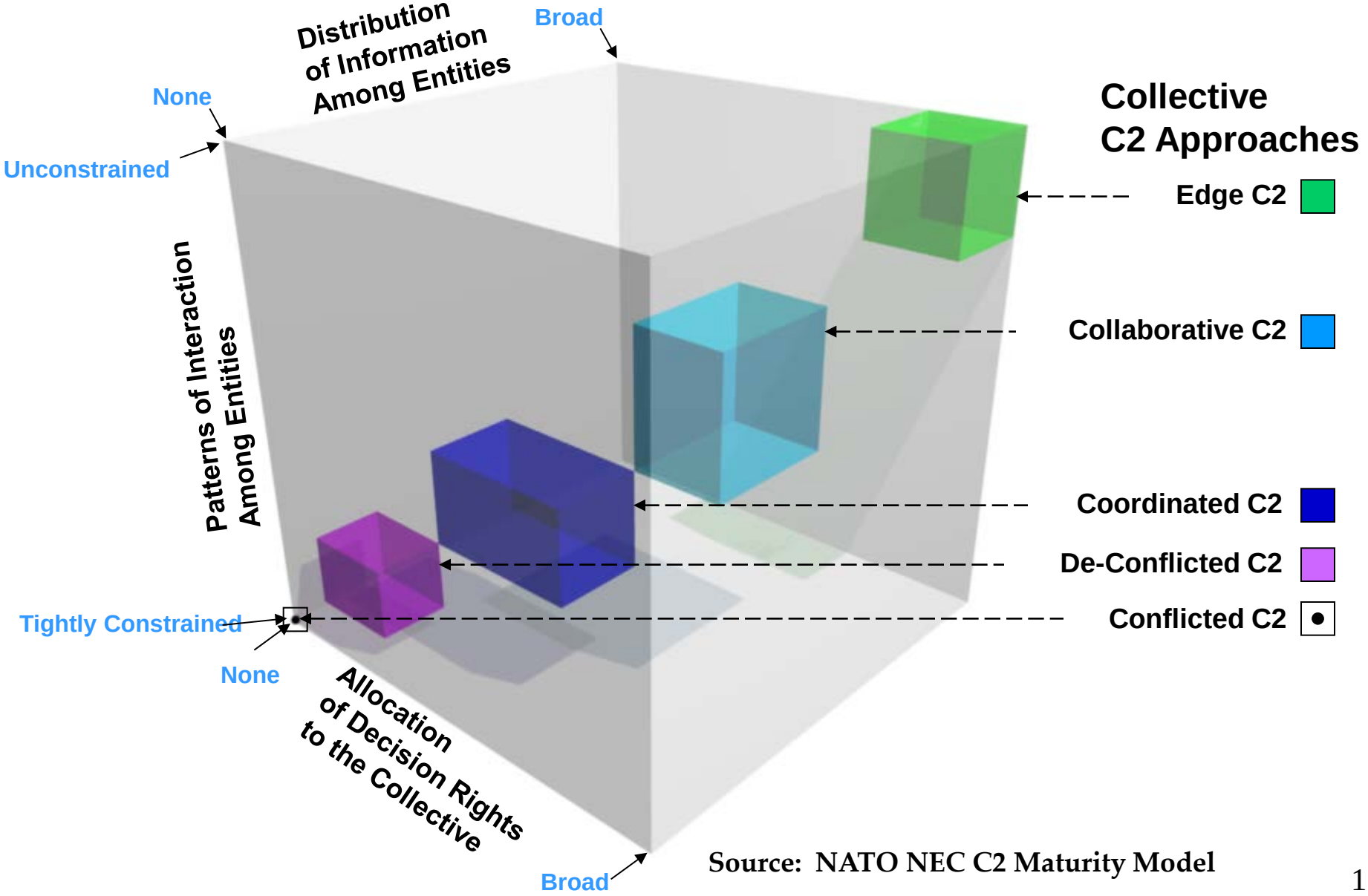
# Patterns of Interactions: Collaborative C2



# Patterns of Interactions: Edge C2



# NATO NEC C2 Approaches




Source: NATO NEC C2 Maturity Model

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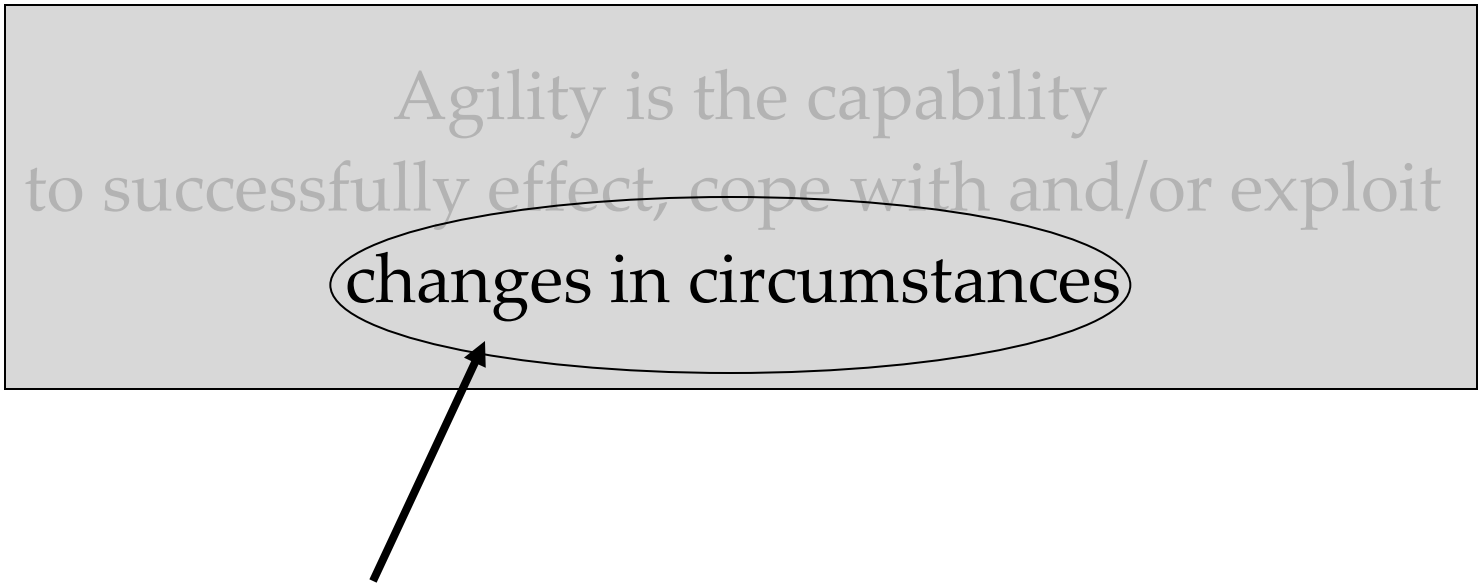
# What is Agility?

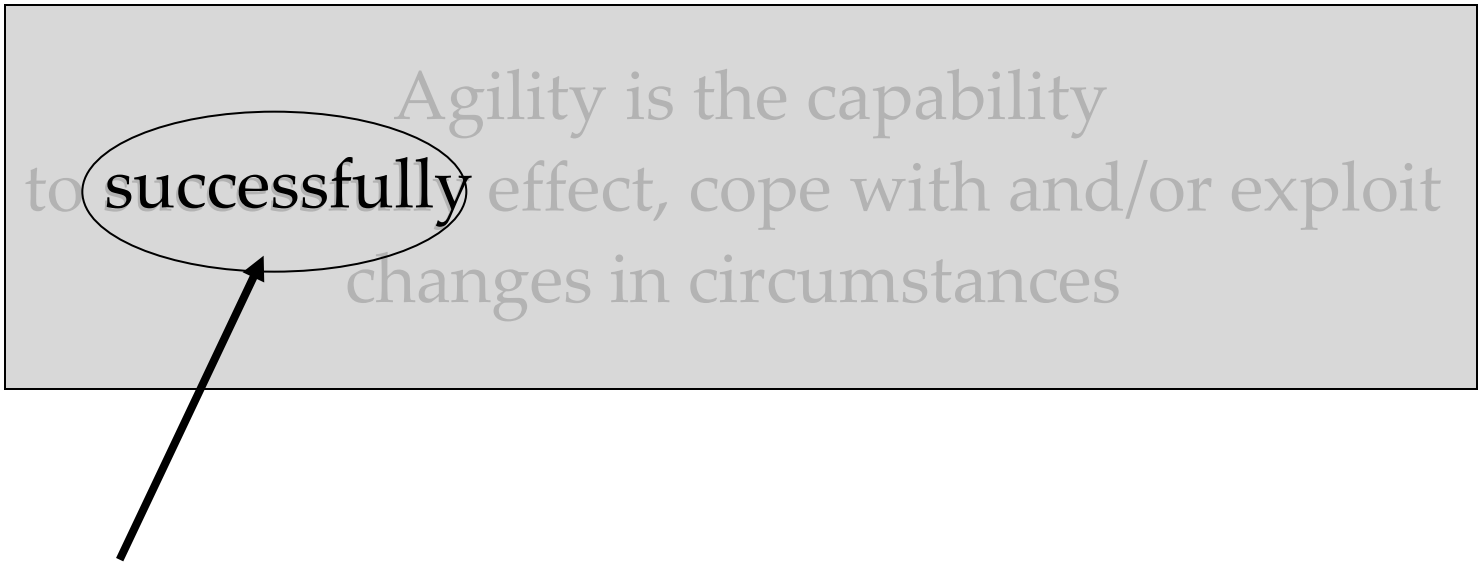
Agility is the capability
to successfully effect, cope with and/or exploit
changes in circumstances

# What is Agility?




- the concept of Agility does not apply to a stable situation
- external changes (e.g. regime change, permissive to hostile)
- changes to self (e.g. a new coalition partner, loss of capability)

# What is Agility?



# What is Agility?

Agility is the capability
to successfully effect, cope with and/or exploit
changes in circumstances

respond to an event that
would otherwise have
adverse consequences

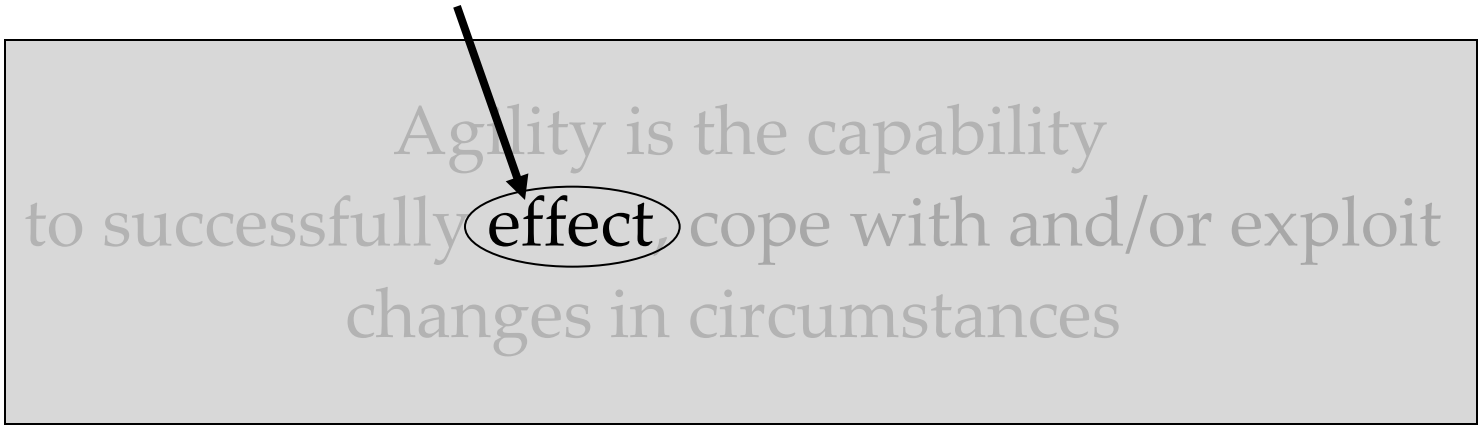
# What is Agility?

Agility is the capability
to successfully effect, cope with and/or exploit
changes in circumstances

take advantage of an opportunity to improve effectiveness and/or efficiency or reduce risk

# What is Agility?

take actions to effect change or to prevent changes that might otherwise occur



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# Components of Agility

- Responsiveness
- Versatility
- Flexibility
- Resilience
- Adaptiveness
- Innovativeness

***The contributions of these components to agility are not additive***

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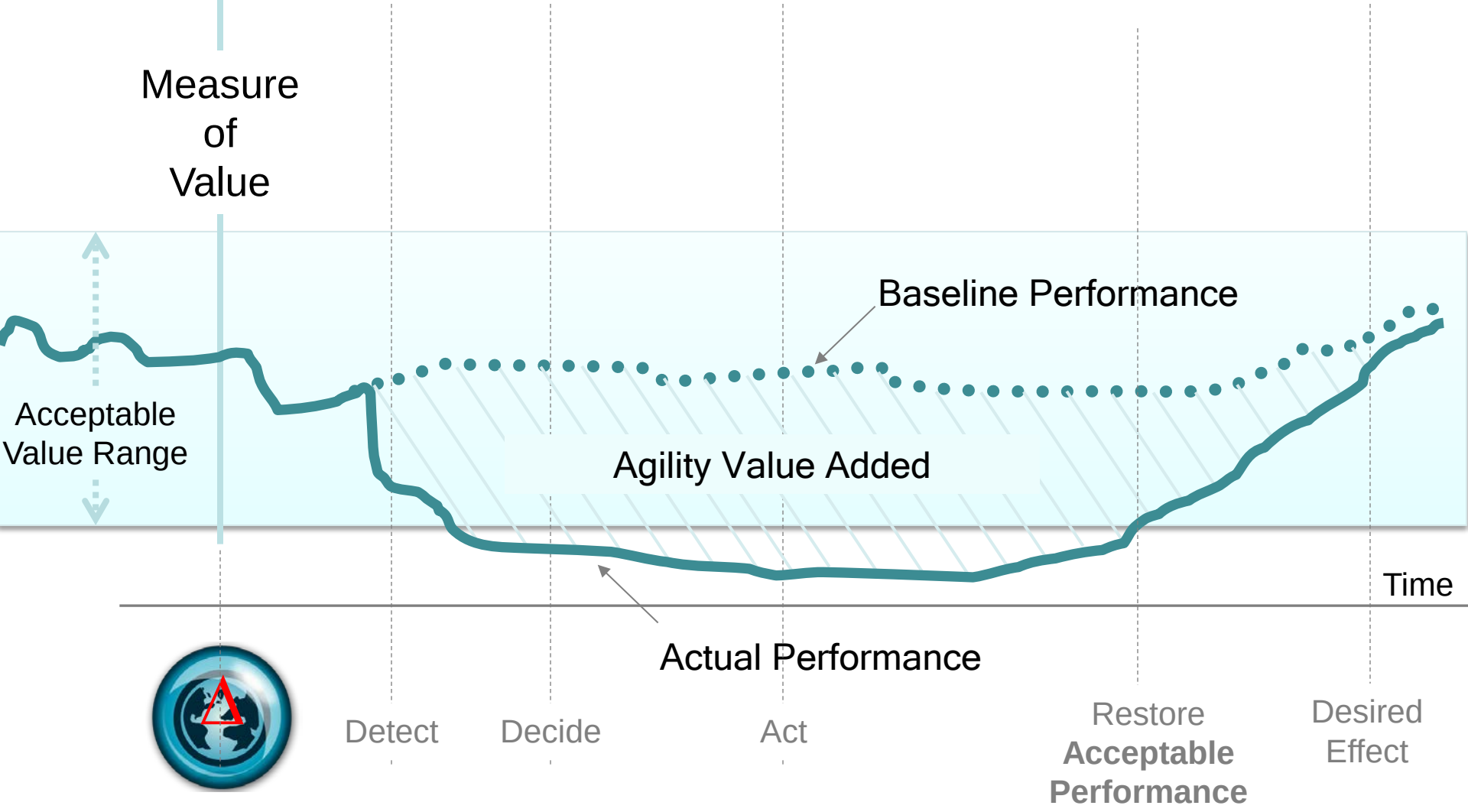
# Responsiveness

- Responsiveness is an essential enabler of Active Agility.
- Responsiveness is a reflection of the timeliness of the intervention(s).
- The efficacy of the intervention is a function of all six of the enablers of agility.

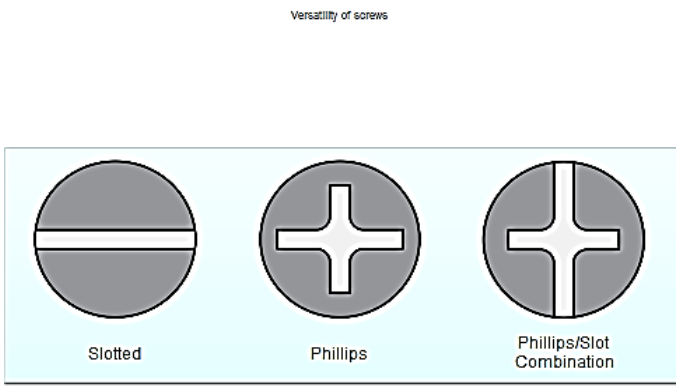
# Anatomy of Responsiveness




**Source: Alberts, The Agility Advantage (2011)**

# Versatility

- Versatility is the passive capability that enables an entity to maintain an acceptable level of performance without having to take action or change oneself.




Screw is able to successfully function under multiple circumstances (different screw drivers)

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# Flexibility

- *Flexibility* is having more than one way to achieve a desired result.
- Having options becomes important if the preferred way cannot be exercised, does not work given the circumstances, or becomes prohibitively costly.
- In theory, the more options one has, the more likely it is that one will have a good option available whatever the circumstances.
- As the number of options in one's tool kit increases, the marginal contribution of each additional option gets smaller (the law of diminishing returns).

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# Flexible Tool Kit

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# Resilience

- *Resilience* pertains to changes in circumstances that limit, damage or degrade entity performance.
- Being resilient involves an ability to maintain performance within acceptable bounds despite suffering damage.
- Resilience can be either passive or active or both
  - Being resilient may require that some action being taken (e.g. bring some offline capability on-line) or it may require no action be taken (e.g. existing redundancies provide the protection needed).
  - For example, an appropriately designed network can still provide acceptable services in the event a number of links goes down.

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# Adaptability

- *Adaptability* refers to making changes to self
- In this case, it is not what one does (choose an alternative course of action) that needs to change, but what one is and how one operates.
- Thus, *adaptability* involves changes to organization, policies, and/or processes.

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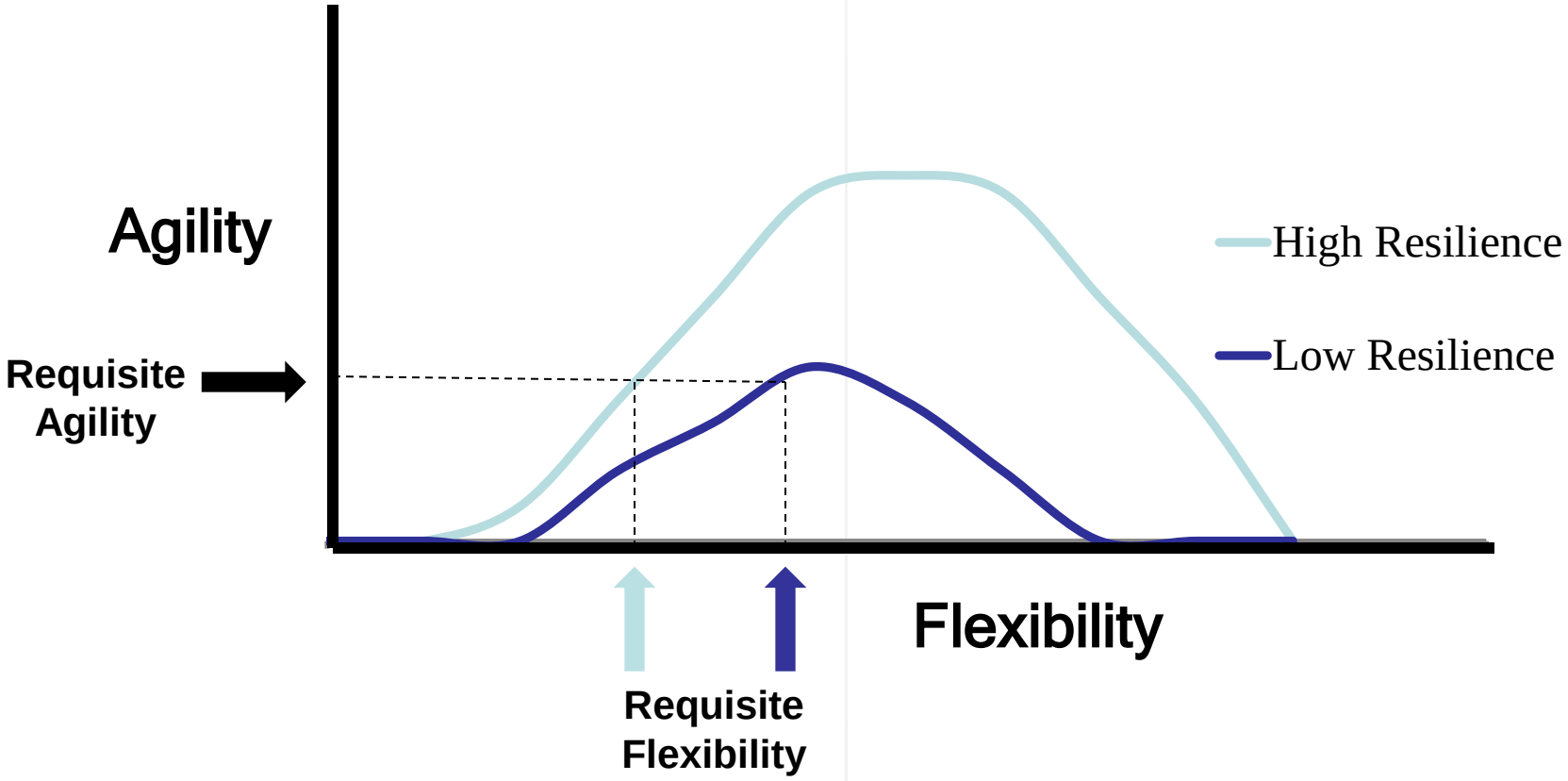
# Innovativeness

- *Innovativeness* involves creating something new
  - e.g. a new way of accomplishing something when current practice does not provide options with adequate performance.
- While *flexibility* refers to having more than one choice, innovativeness adds new ways and means to the toolkit.
- Hence, *Innovativeness* enhances *Flexibility*

# Interdependencies

Requisite Flexibility as a function of Resilience



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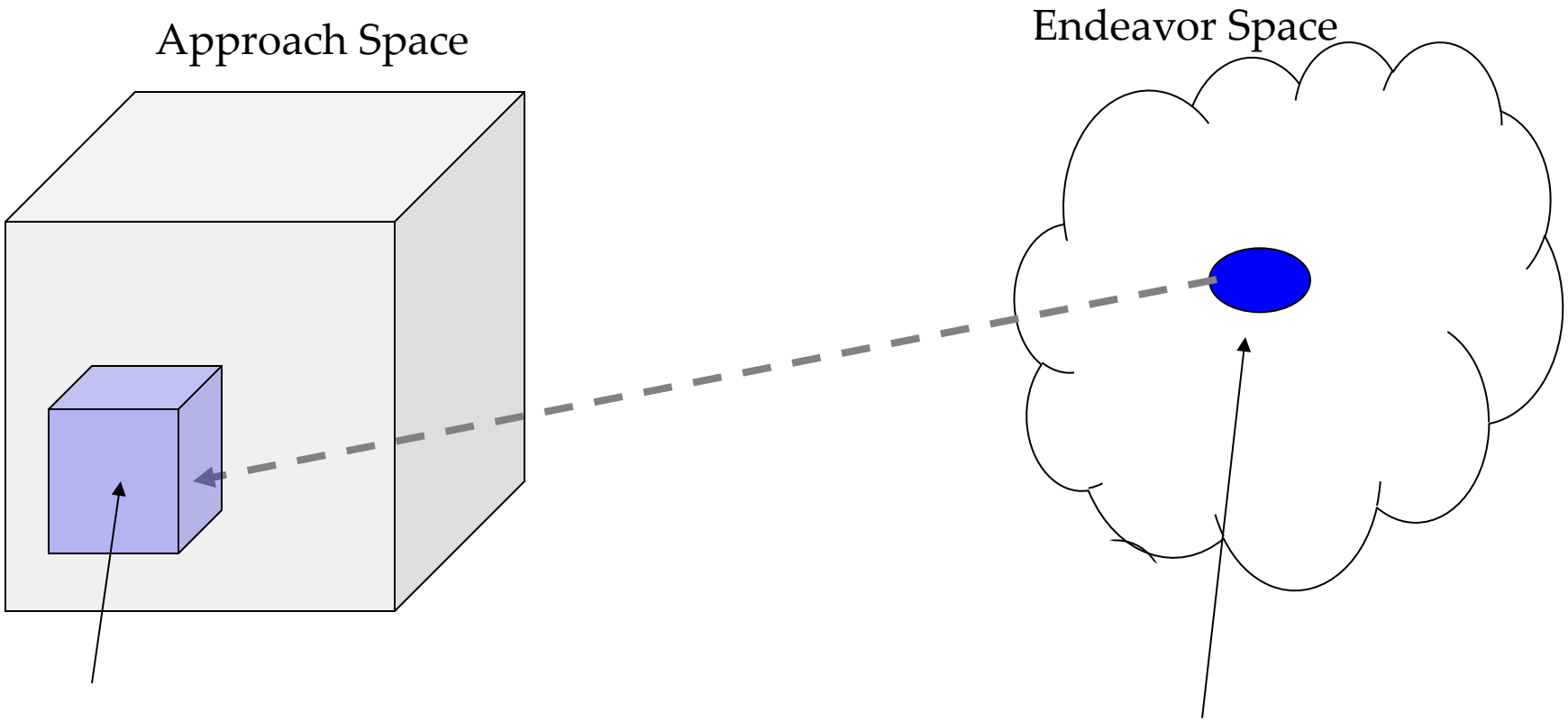
# C2 Agility

- There are *many ways* to accomplish the functions associated with Command and Control
- No one approach to accomplishing the functions associated with command and control fits all missions or situations whether for a single entity or a collection of independent entities (a collective)
- The most appropriate approach will be a function of the endeavor and the prevailing circumstances
- Therefore, Entities (and Collectives) will need to be able to employ more than one approach
- C2 Agility is the ability to appropriately move around in the C2 Approach Space in response to changing missions and circumstances
- Agile C2 systems and processes are required for C2 Agility and to make specific approaches to C2 more agile

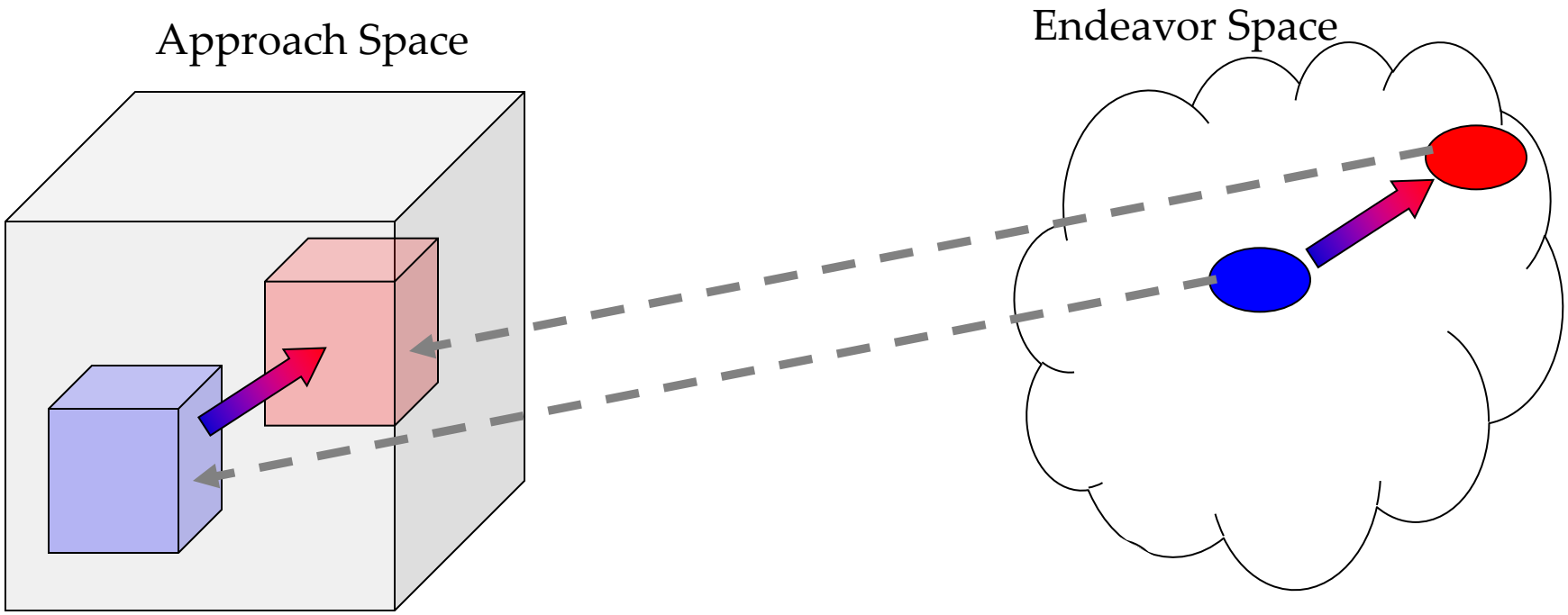
# C2 Agility




***This is a most appropriate C2 Approach for this particular set of circumstances***

# C2 Agility

When circumstances change, a different approach might be more appropriate

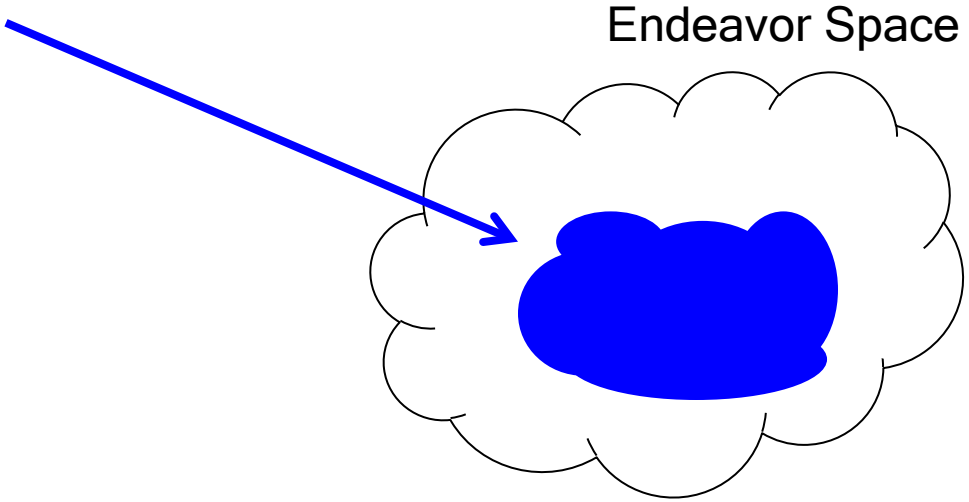



***C2 Agility involves recognizing the significant of a change in circumstances, understanding the most appropriate C2 Approach for the circumstance and being able to transition to this approach.***

# Measuring C2 Agility

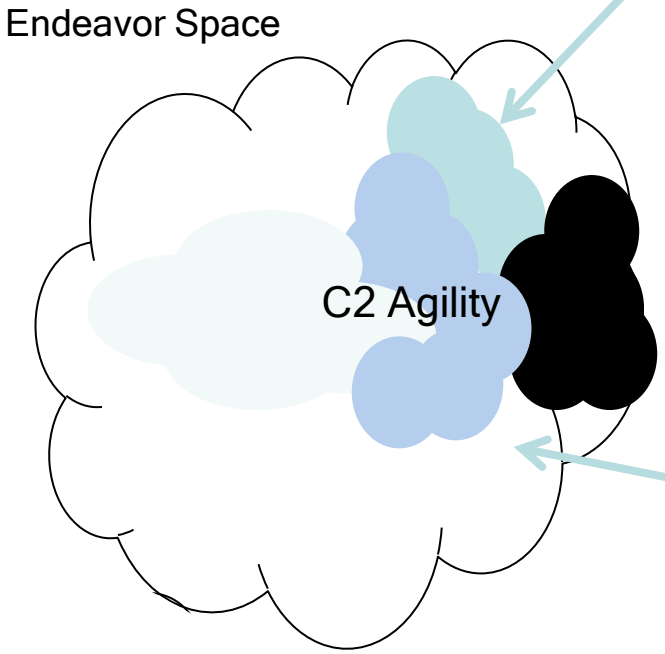
- The degree of agility possessed by an entity is a function of its ability to successful operate over an appropriate set of circumstances (Endeavor Space)
- A scalar measure of agility is defined as the area of the region in the Endeavor Space where an entity can successfully operate

$$\text{Agility} = \frac{\text{Area of } \bullet}{\text{Area of } \circ}$$



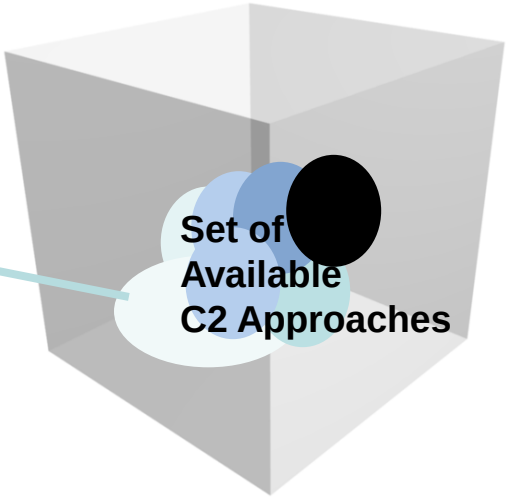
# C2 Agility

- C2 Agility = ***f*** (C2 Approach Agility, C2 Maneuver Agility)

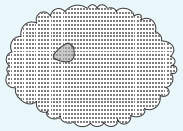



**C2 Approach Agility is the area of the region in the Endeavor Space where an entity can operate successfully by employing a given approach to C2**

**C2 Maneuver Agility is the ability to recognize the C2 approach appropriate for the circumstances and transition to this approach in a timely manner. It is a function of the set of C2 Approaches available to the entity.**



# Agility of C2 Maturity Levels

| C2 Maturity Levels | Contents of C2 Toolkit | C2 Approach Decision Requirement | Transition Requirements | Region of the Endeavor Space where a collective is successful |
|---|---|---|---|---|
| Level 5 | Edge C2<br>Collaborative C2<br>Coordinated C2<br>De-Conflicted C2 | Emergent | Edge C2<br>Collaborative C2<br>Coordinated C2<br>De-Conflicted C2 |  |
| Level 4 | Collaborative C2<br>Coordinated C2<br>De-Conflicted C2 | Recognize 3 situations and match to appropriate C2 approach | Collaborative C2<br>Coordinated C2<br>De-Conflicted C2 |  |
| Level 3 | Coordinated C2<br>De-Conflicted C2 | Recognize 2 situations and match to appropriate C2 approach | Coordinated C2<br>De-Conflicted C2 |  |
| Level 2 | De-Conflicted C2 | N/A | None |  |
| Level 1 | Conflicted C2 | N/A | None |  |

**Adapted from the Alberts, D. S. (2011). Agility Advantage, CCRP**

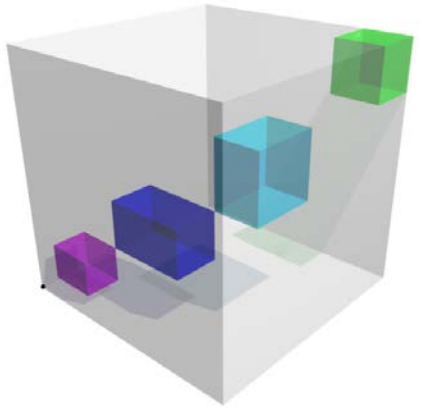
Conflicted De-Conflicted Coordinated Collaborative Edge

# Agenda

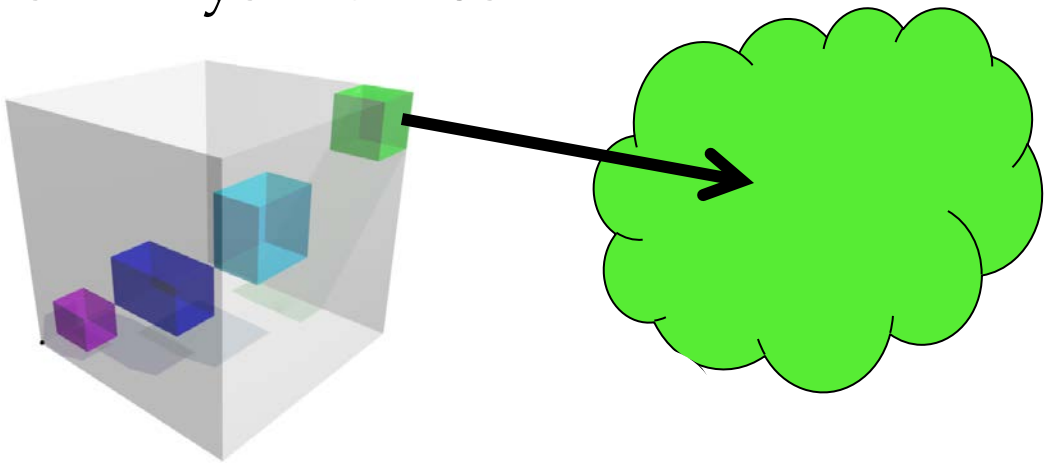
- C2 Agility
- Hypotheses
- Experiments and Results
- Next Steps

# C2 Agility Hypotheses

H1: Each C2 Approach is located in a distinct region of the C2 Approach Space



H2: No one approach is always the most appropriate



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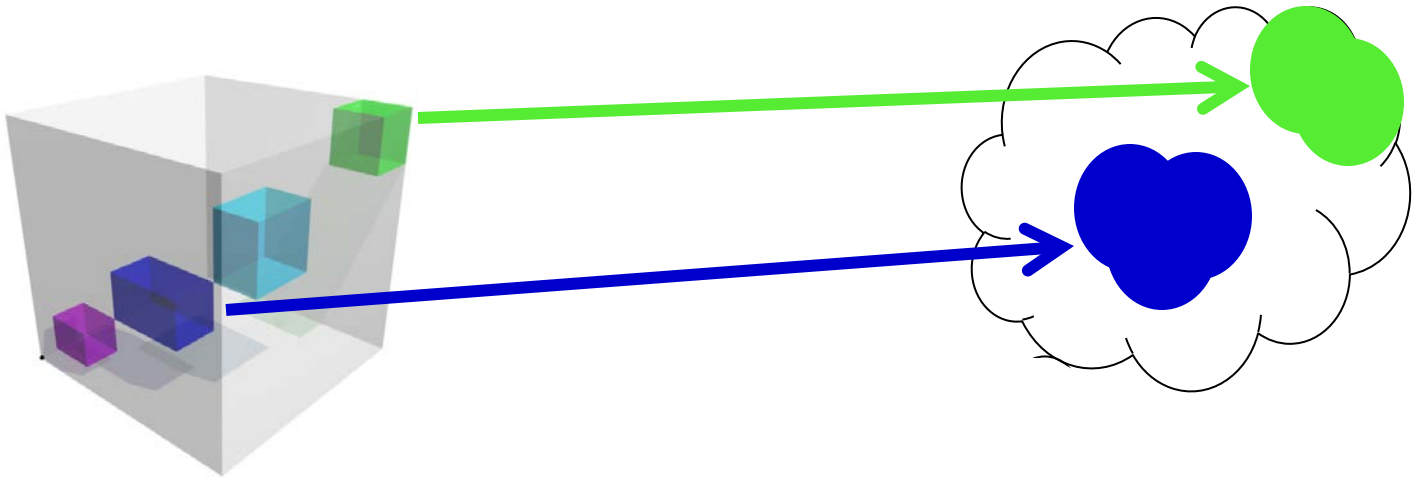
# C2 Agility Hypotheses

H3: More network-enabled approaches are more appropriate for Complex Endeavors; while less network-enabled approaches are more appropriate for less complex missions/circumstances



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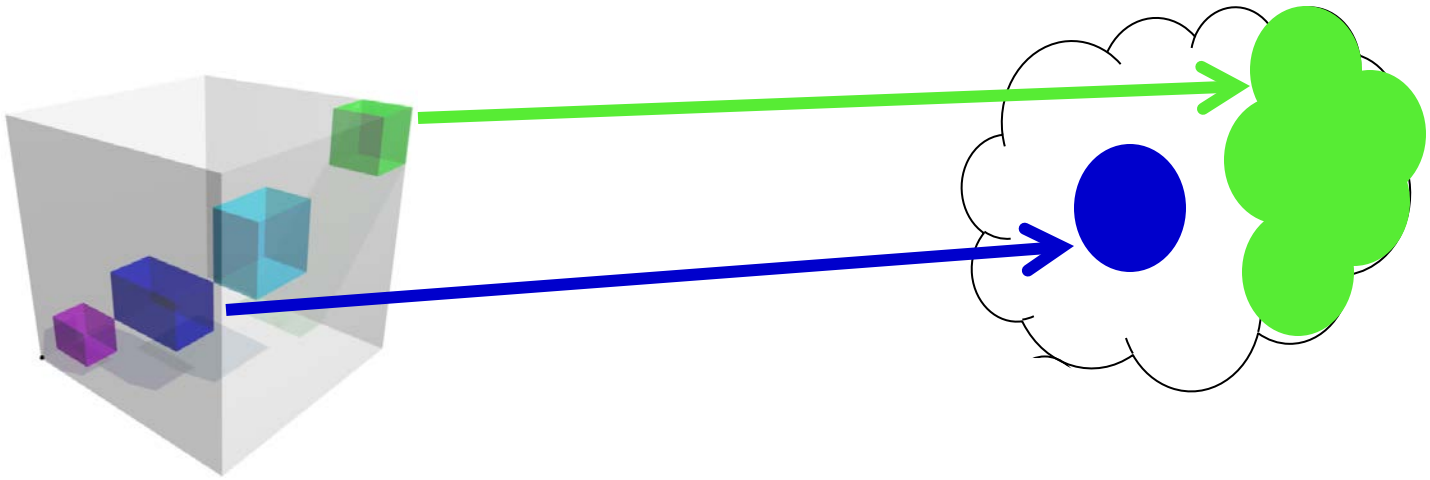
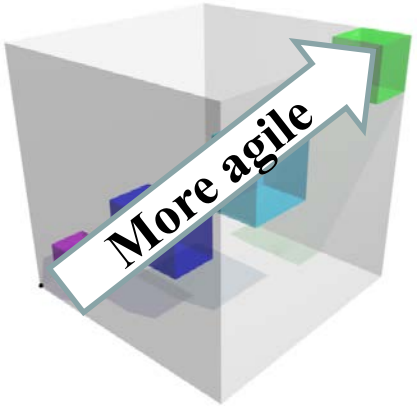
# C2 Agility Hypotheses

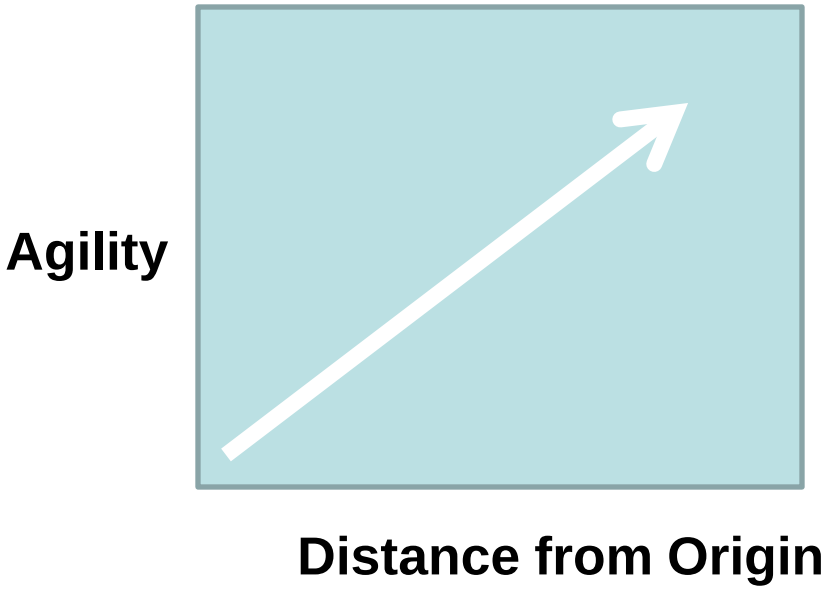
H4: More network-enabled approaches are more agile (have greater C2 Approach Agility)



# C2 Agility Hypotheses

H5: The dimensions of the C2 approach Space are positively correlated with agility



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# C2 Agility Hypotheses

H6: More network-enabled approaches are better able to maintain their intended positions in the C2 Approach Space

H7: On-diagonal (balanced) approaches are more agile

H8: Increasing C2 Maneuver Agility increases agility

H9: More mature C2 capability is more agile than the C2 Approach Agility of the most network-enabled approach available

H10: Self monitoring is required for C2 Maneuver Agility

H11: The six enablers of agility are collectively exhaustive and thus all instances of observed agility can be traced to one or more of these enablers

H12: Each of these enablers is positively correlated with agility

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# Agenda

- C2 Agility
- Hypotheses
- Experiments and Results
- Next Steps

# C2 Agility Experimentation

- DoD CCRP ELICIT
- SAS-085 Campaign of Experimentation (CAMPX)
- ARL Network Science Research Laboratory

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# DoD CCRP ELICIT

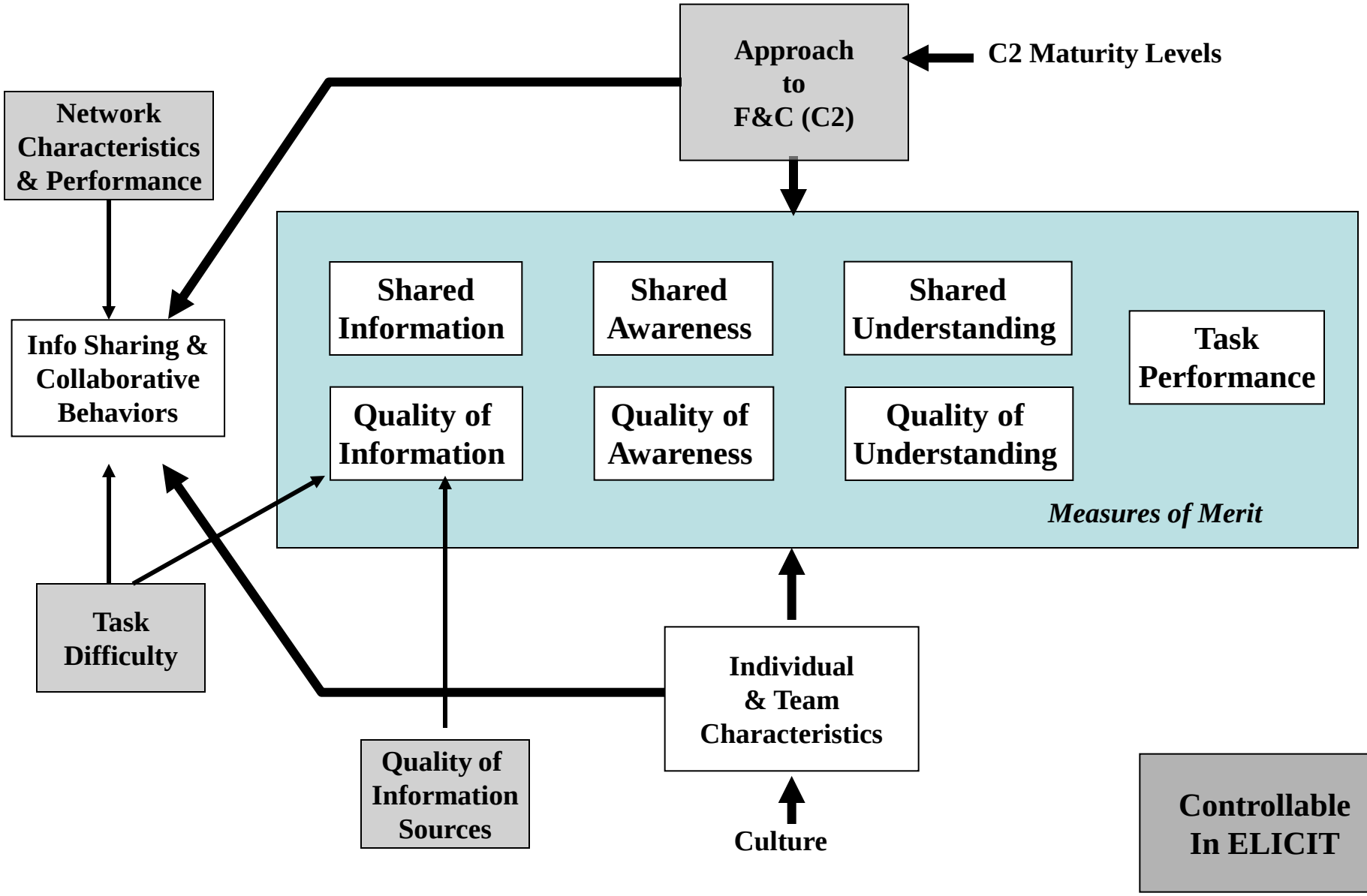
**E**xperimental **L**aboratory for the **I**nvestigation of **C**ollaboration **I**nformation-sharing and **T**rust

- The U.S. DoD (OASD/NII) Command and Control Research Program (CCRP) sponsored the design and development of the ELICIT platform for experimentation and classroom activities focused on information, cognitive, and social domain phenomena

- The purpose of ELICIT-related experimentation, teaching, and analysis is to investigate the cognitive and social impacts of C2 approach and organizational structure (e.g. information sharing, trust, shared awareness, and task performance)

- ELICIT features:
  - An instrumented environment
  - Flexibly configurable C2 approaches
  - Supports both person-in-the-loop and software agents
  - Context provided by instructions/procedures/data files

# Controllable in ELICIT



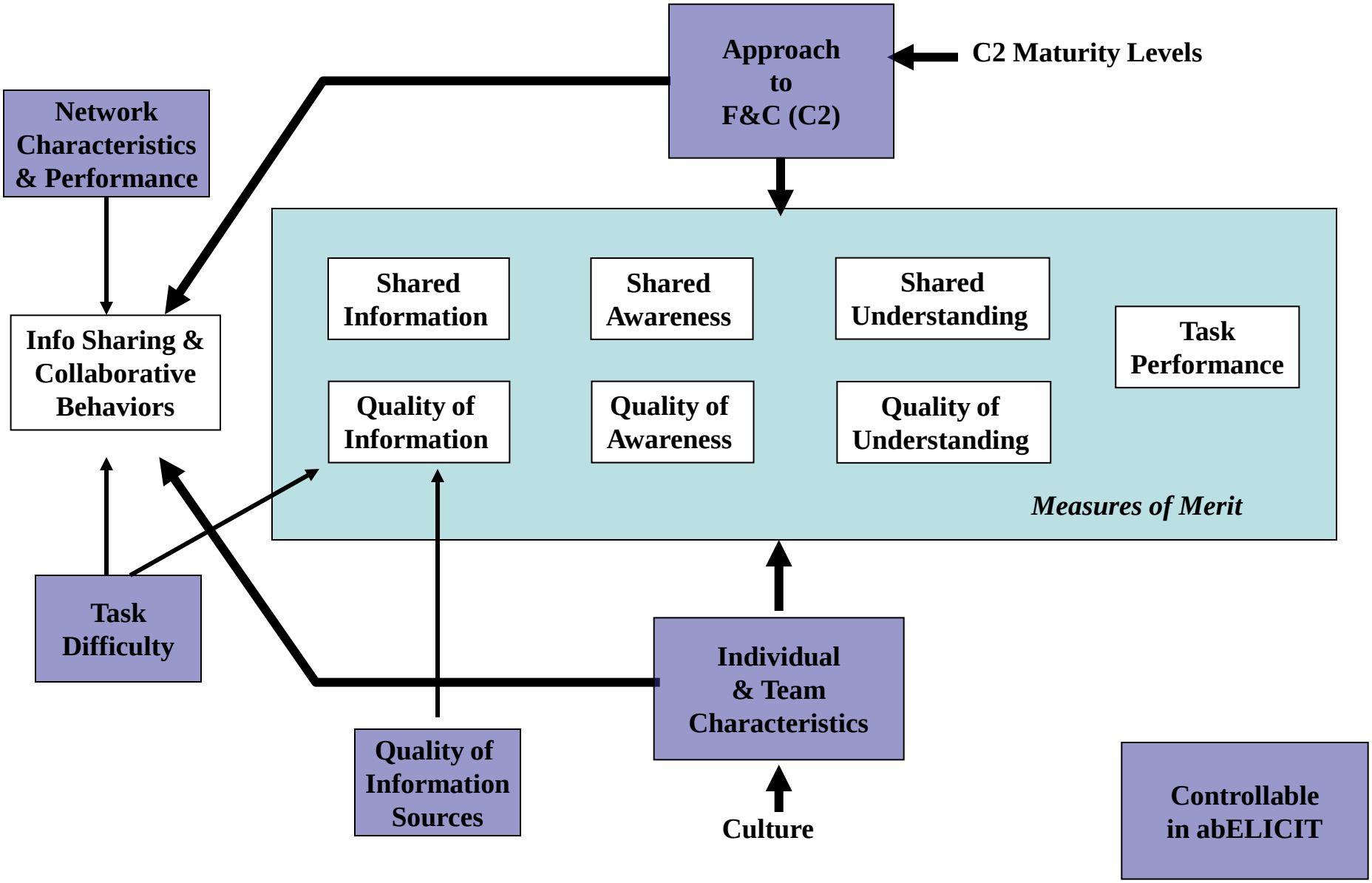
# Hierarchy – Edge

Measures of Effectiveness and Efficiency
Results of Human Trials

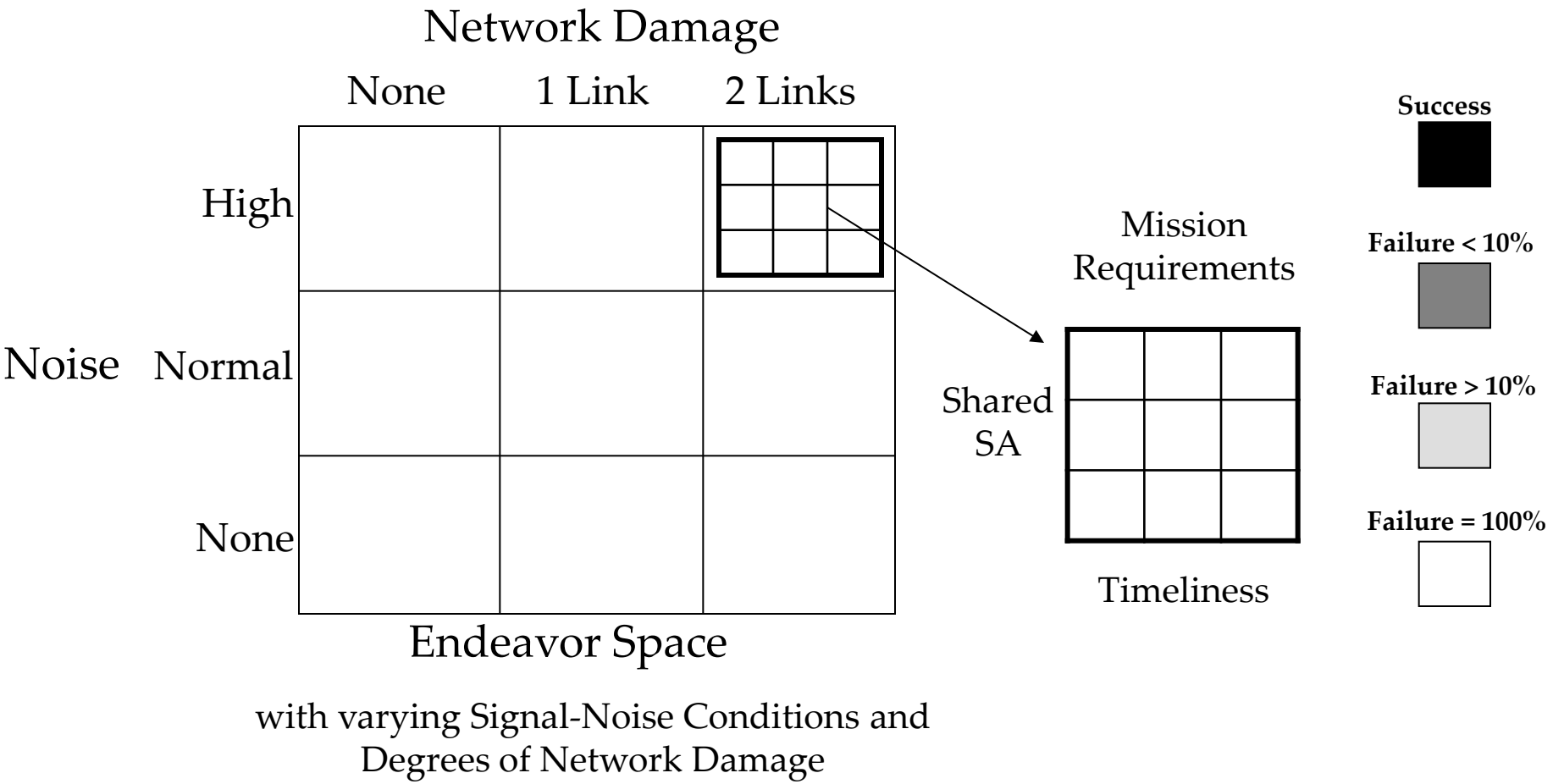
| | Average Correctness | Average Timeliness | Average Efficiency | Average Error Rate |
|---|---|---|---|---|
| Hierarchy | .025 | .013 | .011 | .549 |
| Edge | .193 | .080 | .044 | .426 |

*Alberts, The Agility Advantage (2011) Results from 7 matched sets (14 human trials)

# Controllable in abELICIT



# Agility Map for Edge C2
## (with an adaptive information sharing policy)

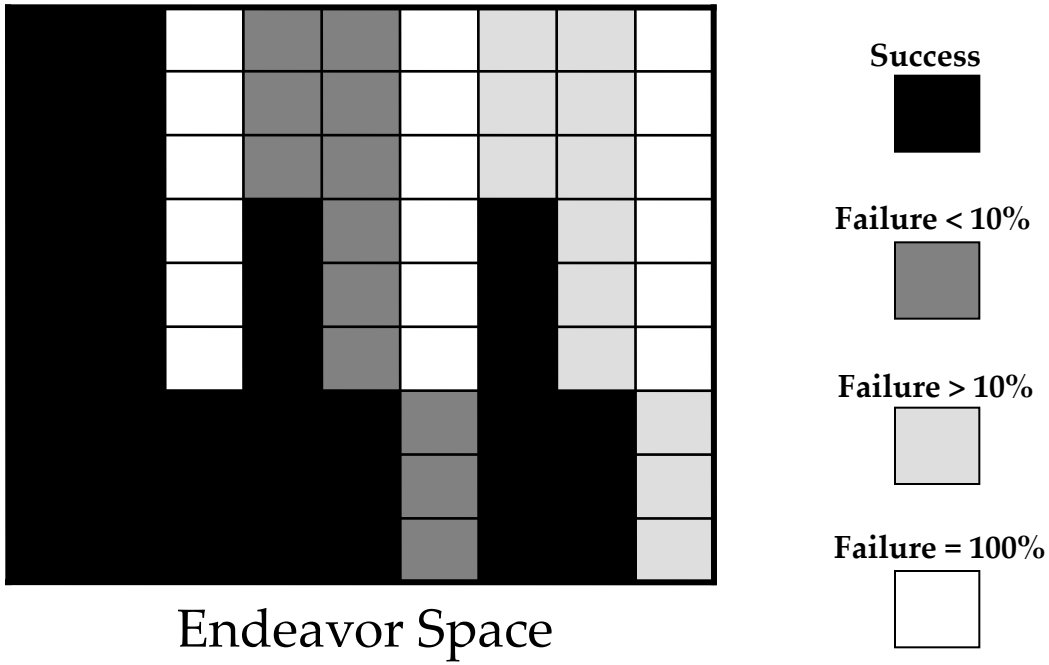



with varying Signal-Noise Conditions and Degrees of Network Damage

**Source: Alberts, D.S. The Agility Imperative, 2010 Part V: Agility Experiments**

# Agility Map for Edge C2
## (with an adaptive information sharing policy)

Source: The Agility Advantage CCRP Publications 2011

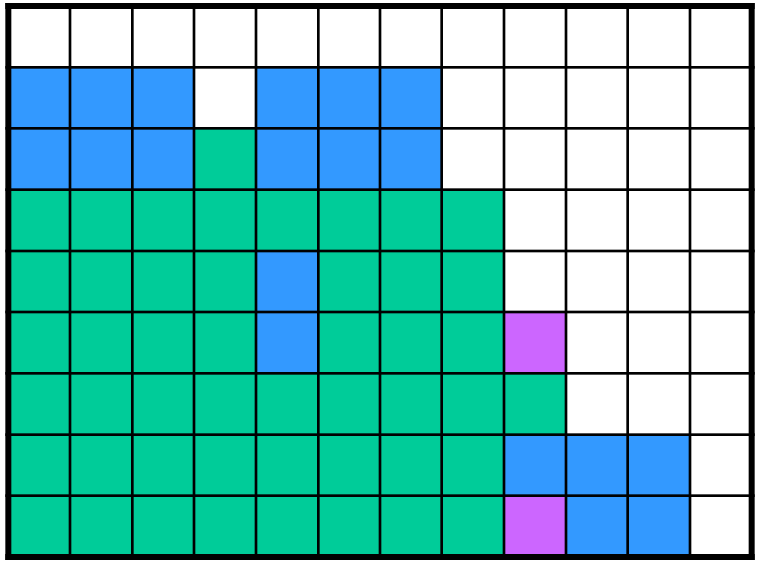



Endeavor Space

with varying Signal-Noise Conditions and
Degrees of Network Damage

Source: Alberts, D.S. The Agility Imperative, 2010 Part V: Agility Experiments

# Comparative Agility Map




Endeavor Space

with varying conditions of signal to noise
and with varying requirements
for shared situation awareness and response time

**Source: Alberts, D.S. The Agility Imperative, 2010 Part V: Agility Experiments**

# C2 Agility Experimentation

- DoD CCRP ELICIT
- SAS-085 Campaign of Experimentation (CAMPX)
- ARL Network Science Research Laboratory

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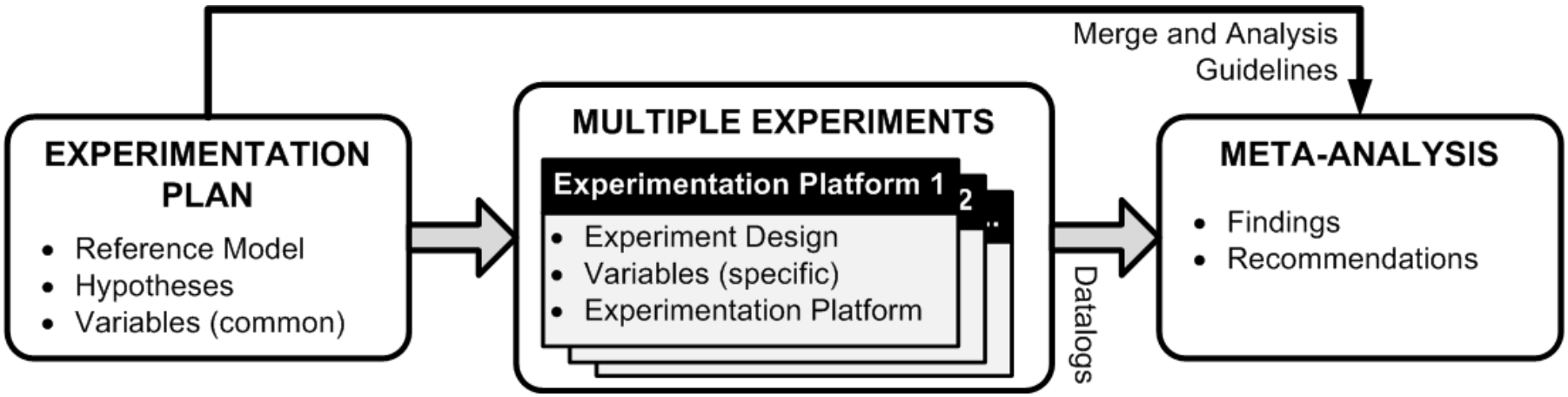
# SAS-085 CAMPX Methodology

- The method followed is based on the prospective meta-analysis methodology in order to produce a more complete, robust and generalizable set of findings than summarizing multiple independent experiments



# SAS-085 CAMPX Experimental Platforms

- All experimental platforms are constructive agent-based simulations, each of which instantiates at least two C2 Approaches and simulates a variety of circumstances
- ELICIT: Scenario that finds the Who, What, Where and When of a terrorist attack. There are three variants:
  - ELICIT-IDA (U.S.A.)
  - abELICIT (Portugal)
  - ELICIT-TRUST (U.S.A.): agents are influenced by trust
- IMAGE (Canada): Multi-agency stabilization operation
- WISE (U.K.): Air and maritime support to land operation
- PANOPEA (Italy): Maritime counter-piracy operation

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# ELICIT-TRUST

- C2 environments will exist in situations where entities do not trust or there is uncertainty with regard to the behavior of others in the Collective
- ELICIT-TRUST implements sharing behavior between nodes based on trust estimate of other agents
- Trust is a function of competence and willingness.
- Trust evolves according to Bayesian models and agents adapt their behaviors based on estimated trust of neighboring entities
- Communication network effects degrade the flow of information

# ELICIT Experiment Endeavor Spaces

| | ELICIT- IDA | ELICIT-TRUST | abELICIT |
|---|---|---|---|
| Self | Network damage | Message/Drop rates | Infostructure degradation |
| | | Trust | Agent performance |
| | | Selfishness | Organisation disruption |
| Environment | Challenge | | Key information available |
| | Noise in information | | |
| | Cognitive complexity | | |

# IMAGE

- IMAGE is a complexity comprehension tool augmented with software agents that deliberate and act according to rules that comply as much as possible with N2C2M2 theory
- The scenario involves multiple organizations that try to secure and stabilize the failing state by using a comprehensive approach

**Canadian**

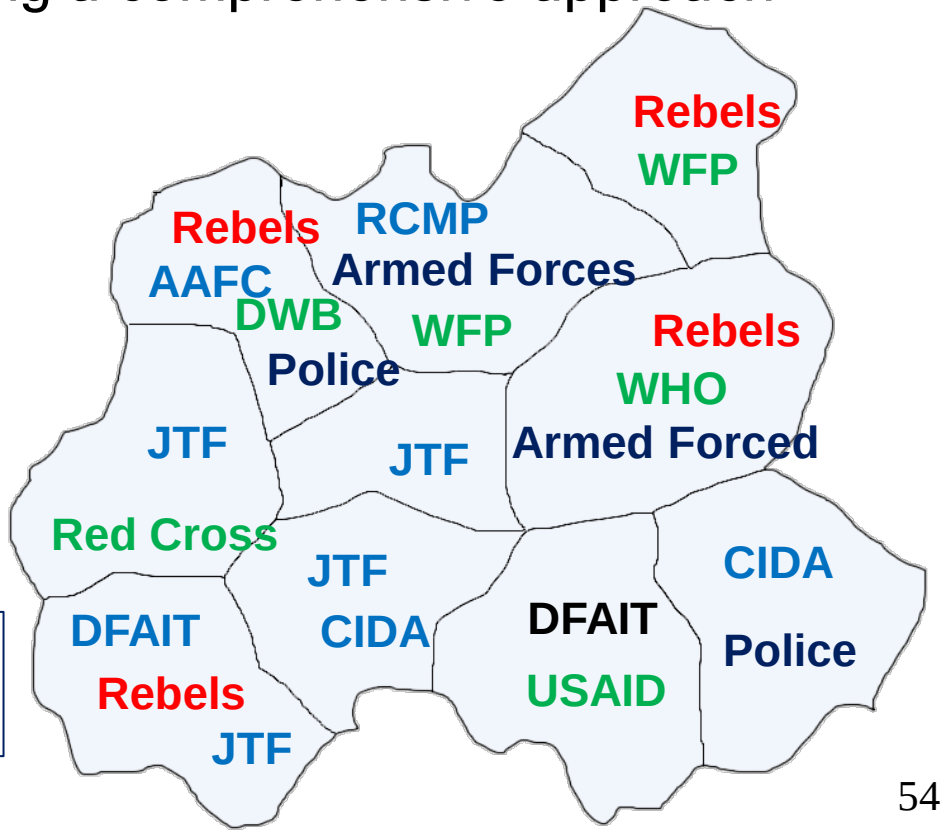
JTF: Joint Task Force
AAFC: Agriculture Canada
CIDA: Canadian International Dev. Agency
DFAIT: Foreign Affair and Int. Trade Canada
RCMP: Royal Canadian Military Police

**International**

DWB: Doctor Without Border
WHO: World Health Organization
WFP: World Food Program
Red Cross
USAID: US Agency Inter. Devel.

**Local**

Armed forces
Police



IDA

# IMAGE

| C2 Approach | Allocation of Decision Rights to the Collective | Patterns of Interaction among Entities | Distribution of Information among entities |
|---|---|---|---|
| **Conflicted** | Each organization decides of its unit locations and activities | Between units of the same organization | Between units of the same organization |
| **De-conflicted** | Each organization decides on its unit locations and non-conflicting activities | With organizations having collocated units for preventing conflicting activities | Variables shared instantly between organizations having collocated units |
| **Coordinated** | Like in De-Conflicted but interacting activities are considered first with collocated units | With organizations having collocated units for considering interacting activities | Like in De-Conficted + variables shared with 5 non-collocated units (delay: 5 iter) |
| **Collaborative** | All activities and unit locations are decided collectively | With all organizations for deciding unit locations and activities. | Same as coordinated but with any number of units (delay 3 iter.) |

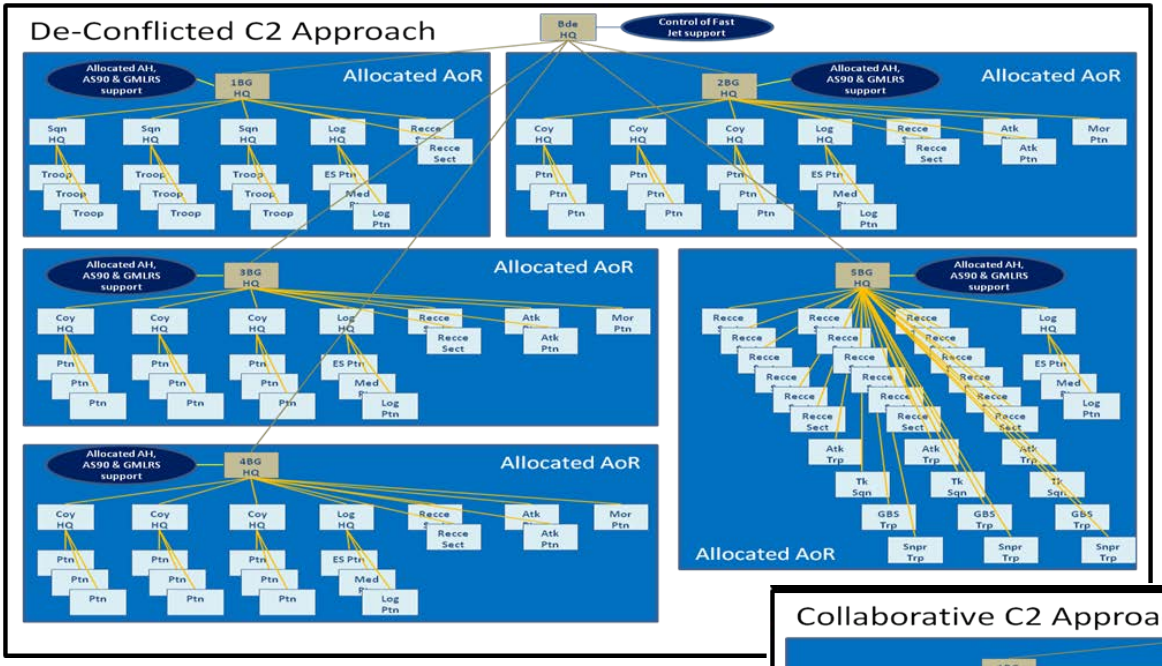
IDA

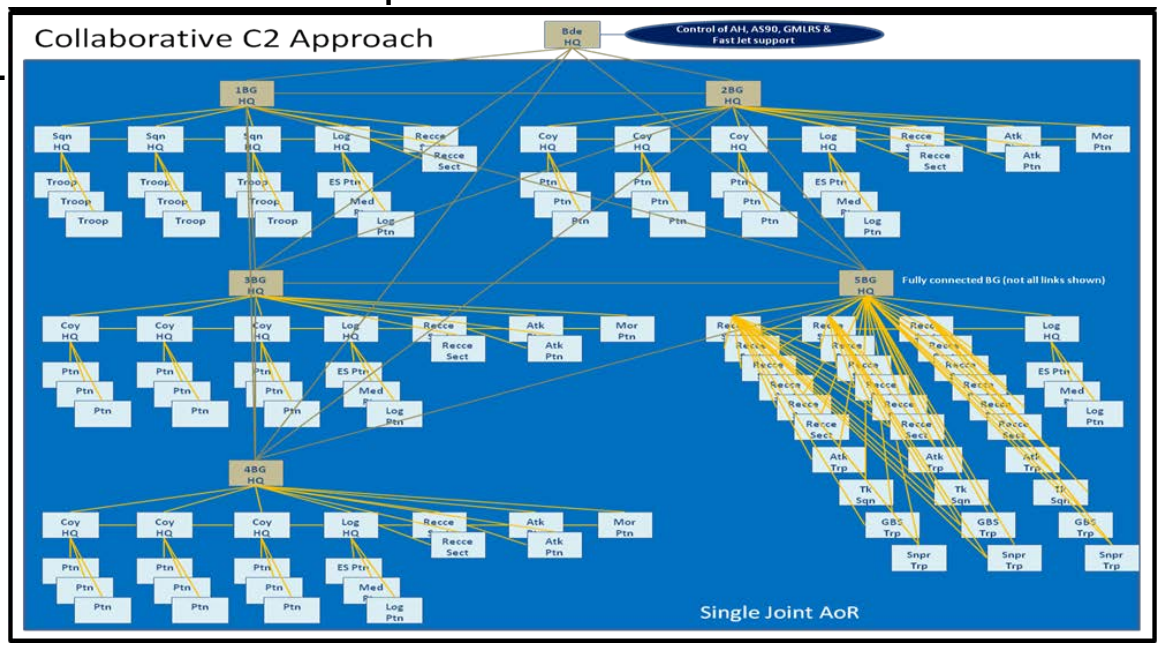
# WISE

- The Wargame Infrastructure and Simulation Environment (WISE) is a Land focused C2 model with representation of air and maritime support to Land operations at the system level
- The scenario simulates a failing state that is experiencing internal conflict. The central government has invited a NATO coalition to stabilize the country
- The UK operation represents a brigade size operation with the specific intent of clearing insurgents from a major urban area
- WISE represented degraded conditions within the brigade operational area by varying the quality of battlefield communication

IDA

# WISE

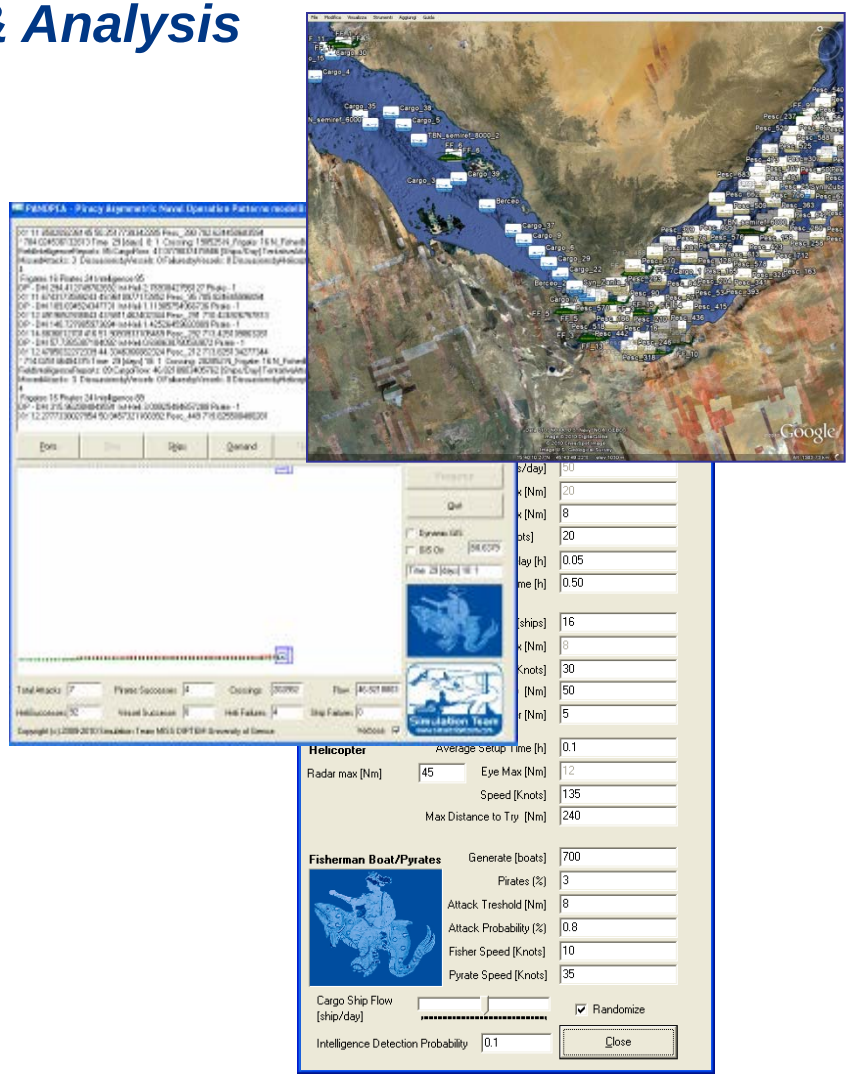

De-Conflicted C2 Approach
Bde HQ
Control of Fast Jet support
1BG HQ
Allocated AH, AS90 & GMLRS support
Allocated AoR
2BG HQ
Allocated AH, AS90 & GMLRS support
Allocated AoR
3BG HQ
Allocated AH, AS90 & GMLRS support
Allocated AoR
4BG HQ
Allocated AH, AS90 & GMLRS support
Allocated AoR
5BG HQ
Allocated AH, AS90 & GMLRS support
Allocated AoR


Collaborative C2 Approach
Bde HQ
Control of AH, AS90, GMLRS & Fast Jet support
1BG HQ
2BG HQ
3BG HQ
4BG HQ
5BG HQ
Fully connected BG (not all links shown)
Single Joint AoR

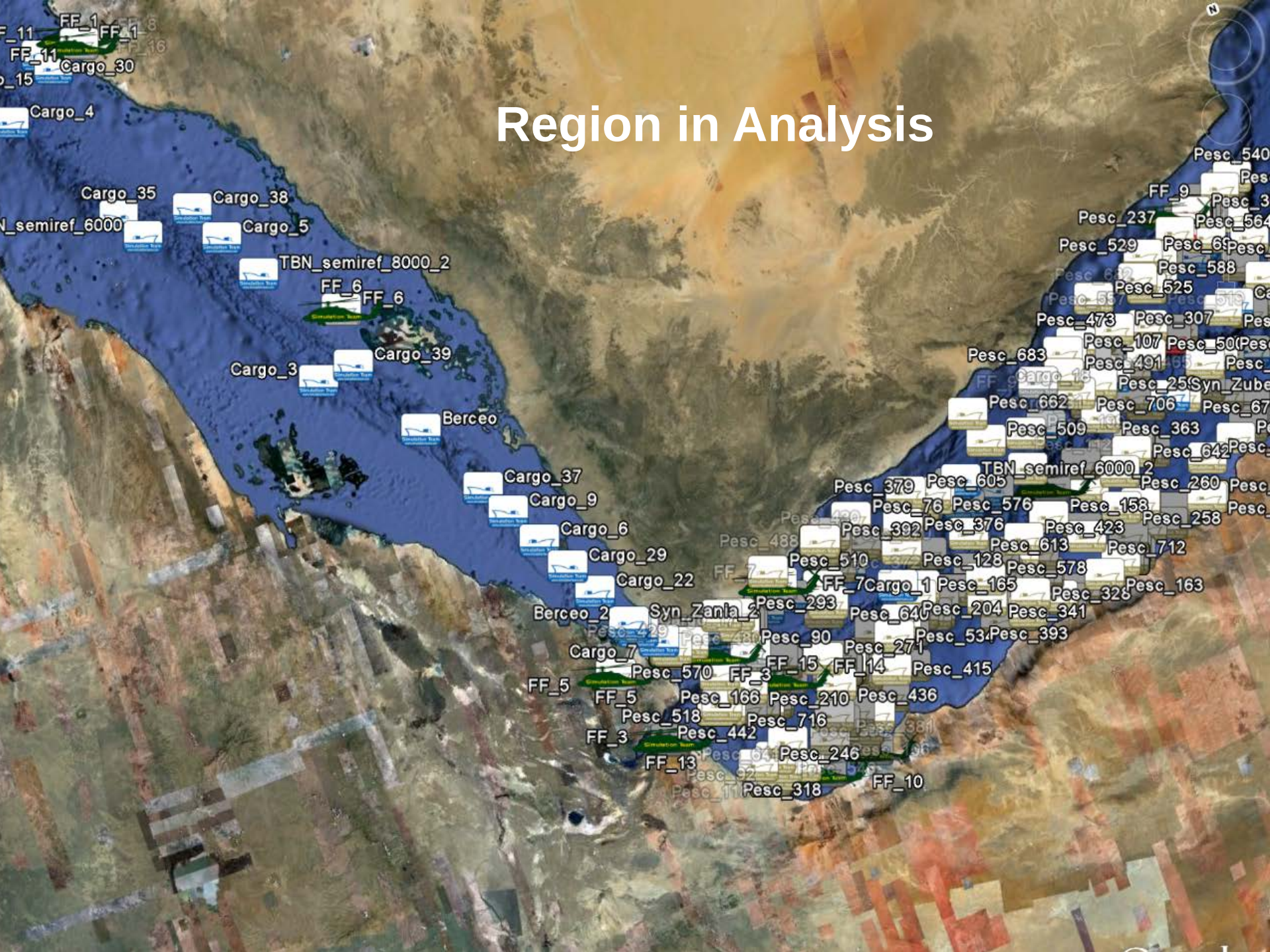
# PANOPEA

***Piracy Asymmetric Naval Operation Patterns modeling for Education & Analysis***

- PANOPEA is a simulator for reproduction of anti-piracy operations and for evaluating the different approaches defined in NEC C2M2
- PANOPEA reproduces military frigates and helicopters, ground base, cargos, fisherman, yachts traffic and pirates
- Units are managed by intelligent software agents



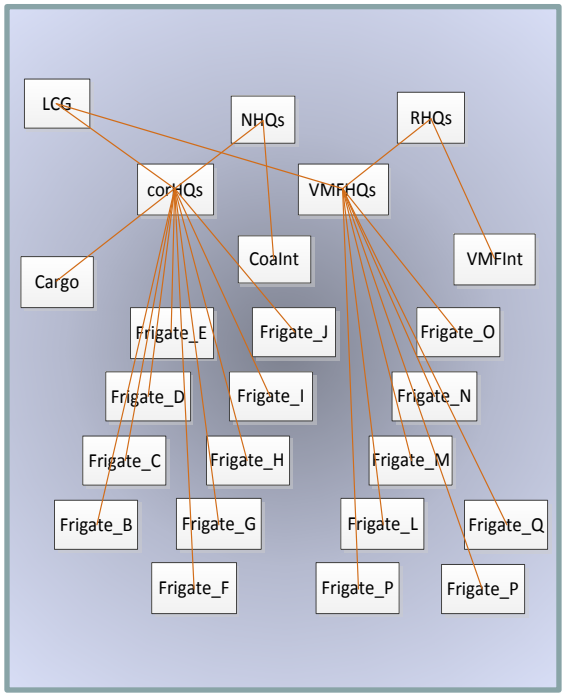
# Region in Analysis



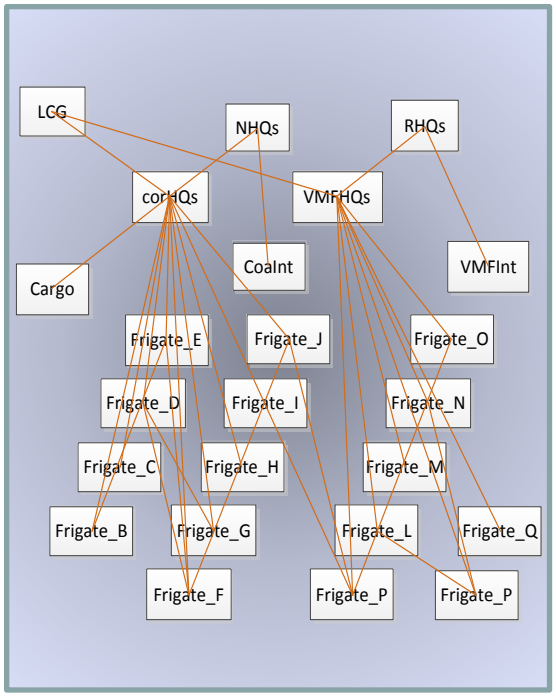
IDA

# PANOPEA

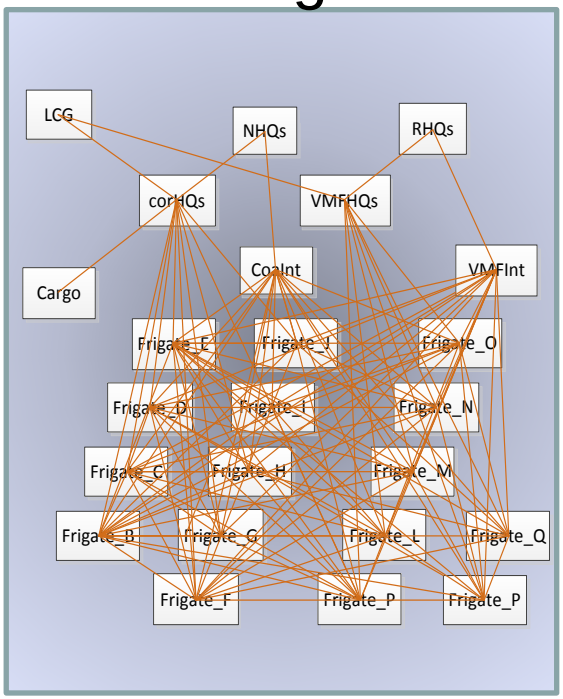
## De-Conflicted



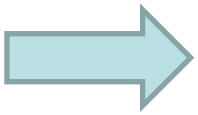

## Collaborative




## Edge




- Ship decision-making capability
- Intelligence DM capability
- Number of pirates
- Weather condition
- Misleading information



Endeavor Space

# CAMPX C2 Approaches Tested

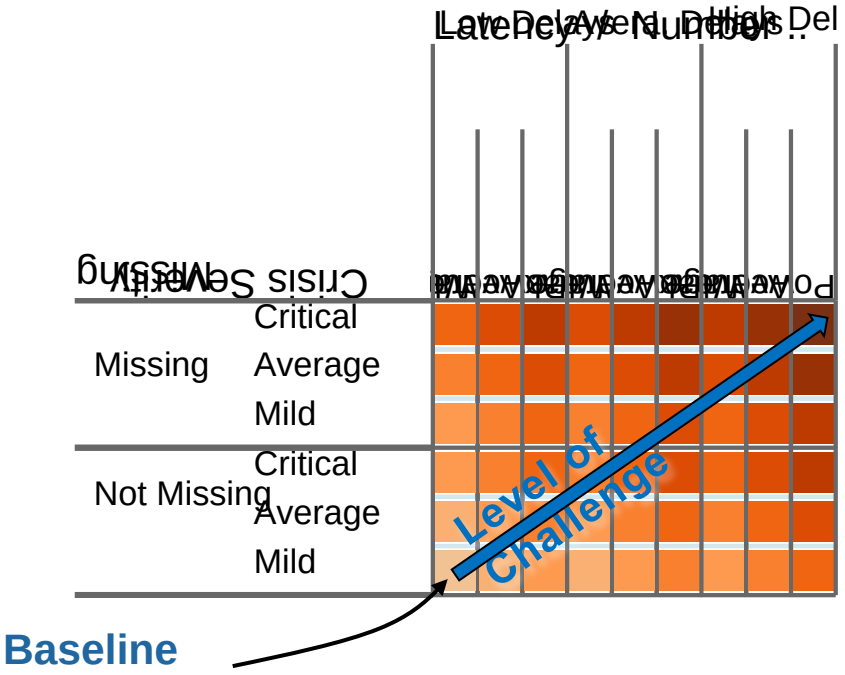
The differences among the experimental instantiations of the C2 approaches was investigated and these were found to be insignificant for the purposes of the CoE

| | ELICIT-IDA (USA) | ELICIT-TRUST (USA) | abELICIT (Portugal) | IMAGE (Canada) | WISE (UK) | PANOPEA (Italy) |
|---|---|---|---|---|---|---|
| Conflicted | | X | | X | | |
| De-Conflicted | X | X | | X | X | X |
| Coordinated | X | X | X | X | | |
| Collaborative | X | X | X | X | X | X |
| Edge | X | X | X | | | X |

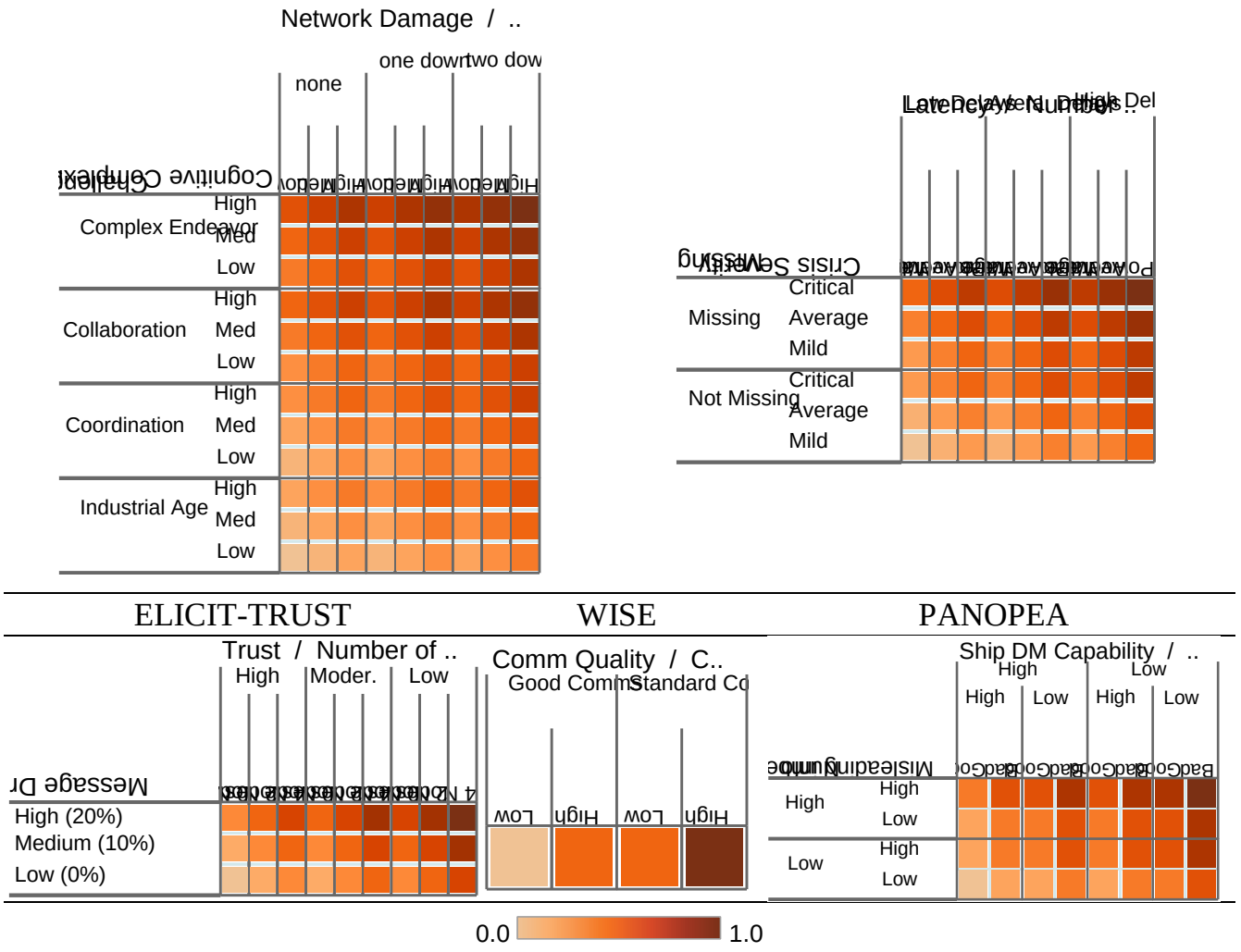
*Not all of the experiments implemented all of the C2 Approaches*

# Creating an Endeavour Space

- The Endeavor Spaces were populated by combining all possible values of multiple variables, each one corresponding to an aspect of the situation
- Heat maps show the progressive degree of challenge of the Endeavour Spaces
  - Darker shades of orange represent most challenging circumstances
  - Values were normalized across the experiments



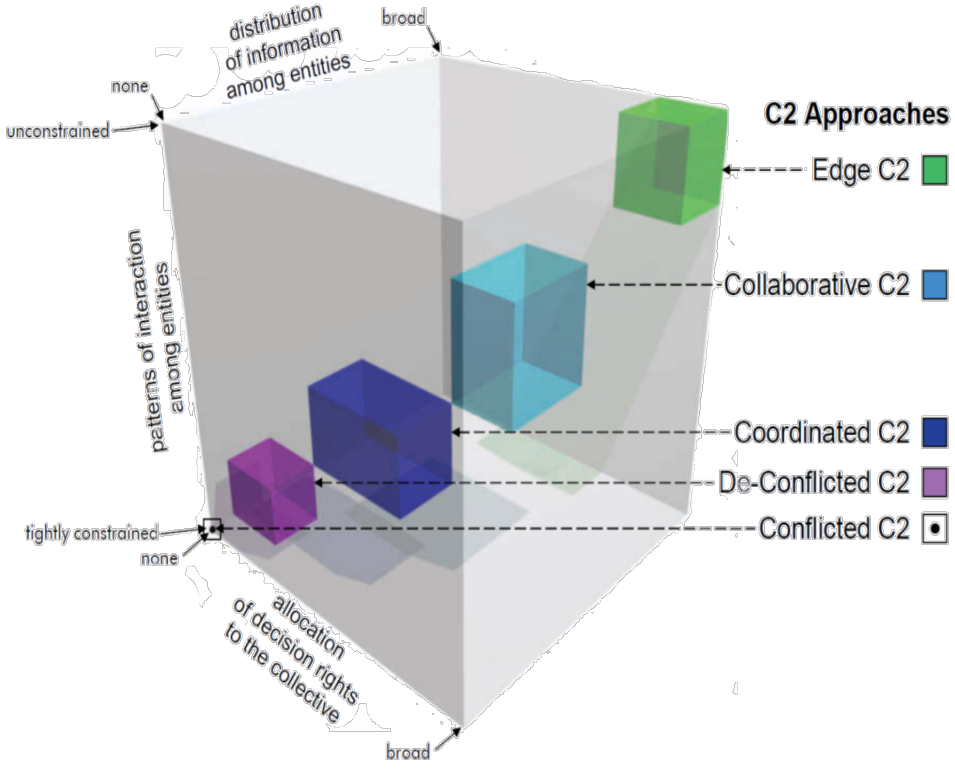
# SAS-085 CAMPX Endeavour Spaces



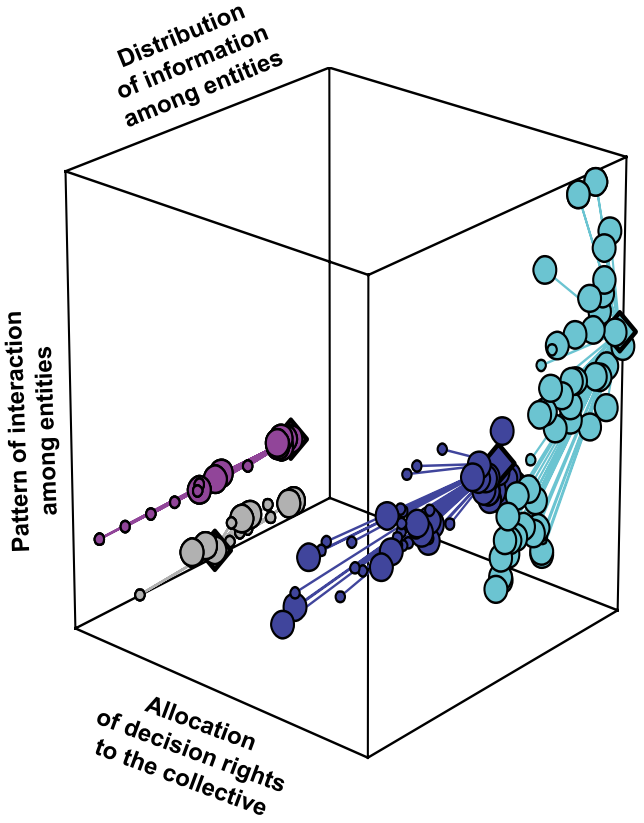
# Approaches in the C2 Approach Space

H1: Each of the NATO C2 Maturity Model approaches is located in a distinct region of the C2 Approach Space

## Theoretical Locations



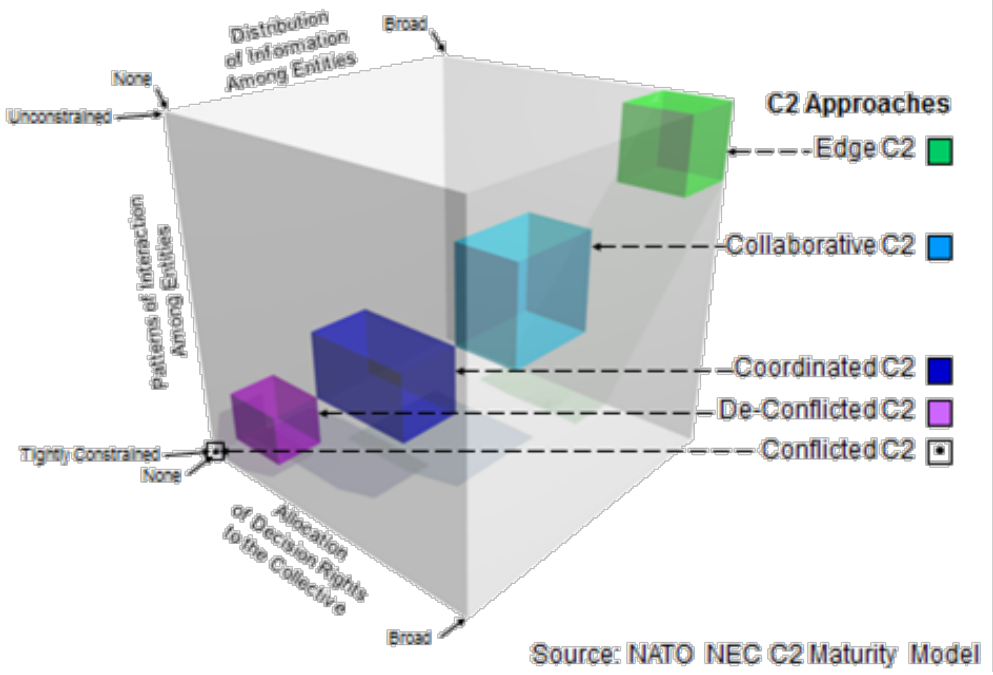

## Observed Locations (IMAGE)



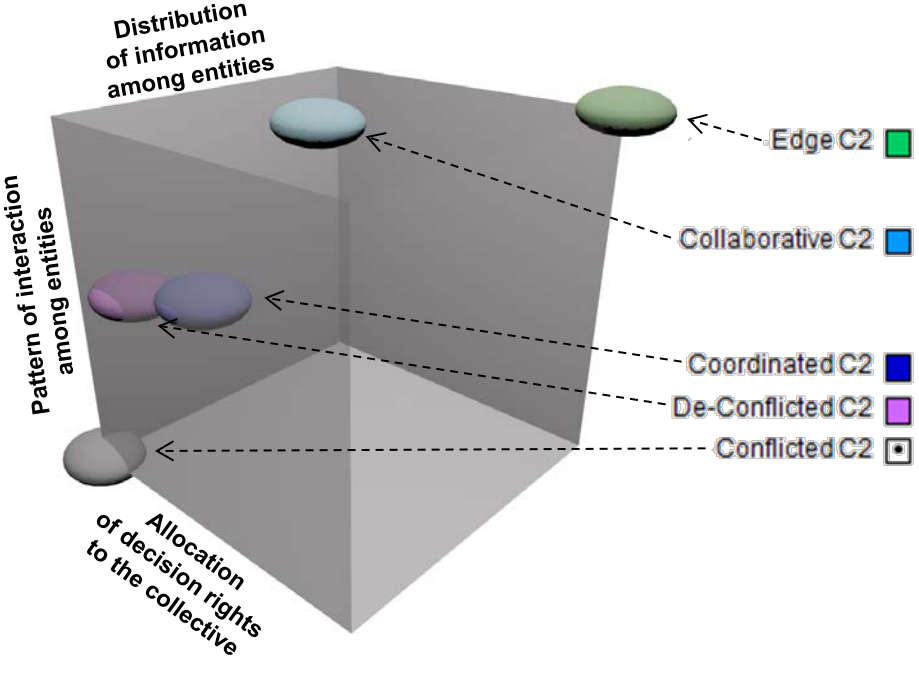

Success  Failure  Baseline  Degraded Conditions

# C2 Approach Locations – Meta Analysis

## Conceptual Model




## Experimental Results

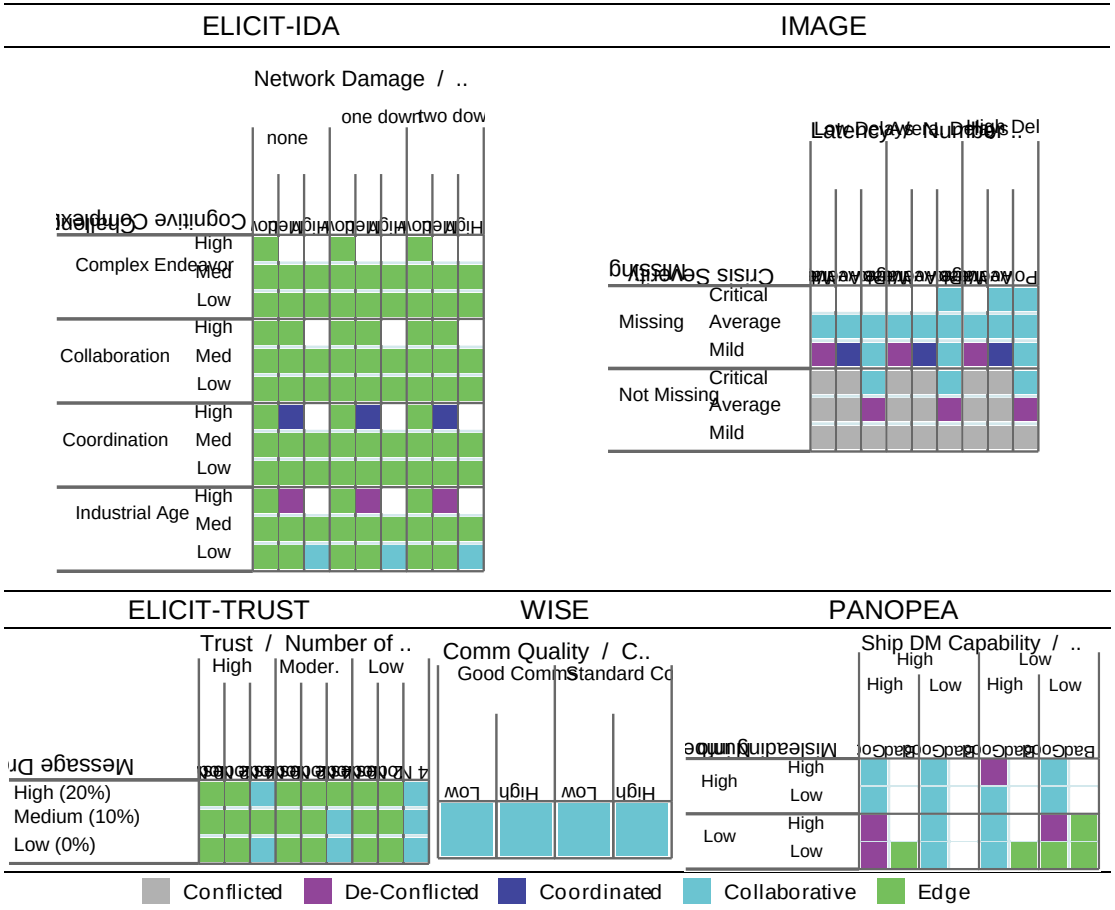



*Combined results show that C2 approaches are located in distinct regions of the C2 Approach Space*

# No 'One Size' Fits All

H2: No one approach to C2 is always the most appropriate

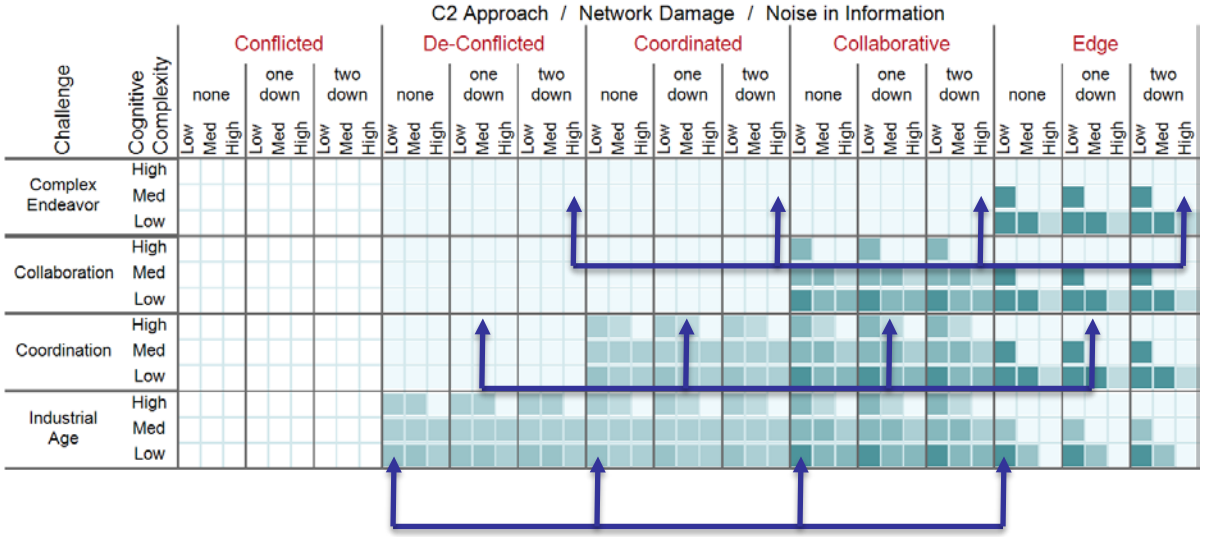
H3: More network-enabled approaches to C2 are more appropriate for more challenging circumstances; however, less network-enabled C2 approaches to C2 are more appropriate for some circumstances

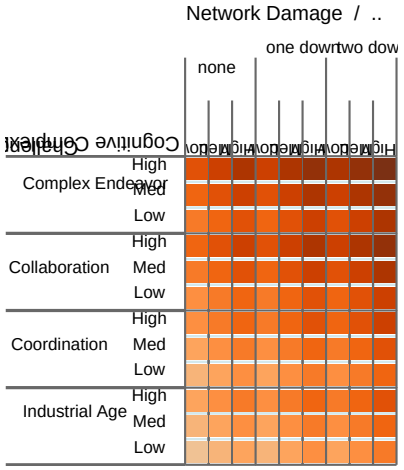


# More Network-Enabled = More Agility

H4: More network-enabled approaches to C2 are more agile

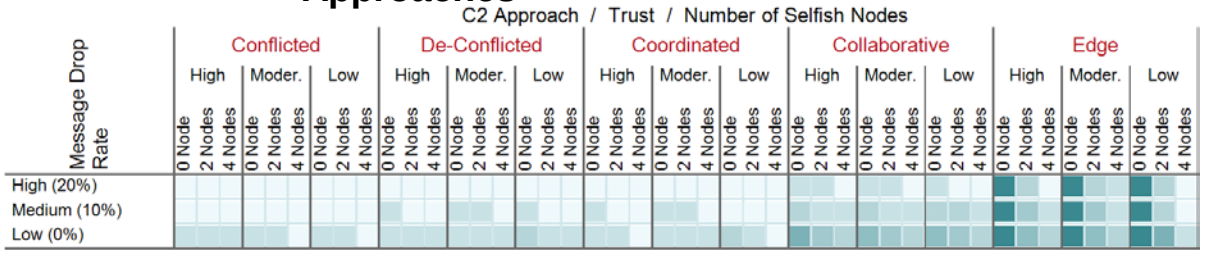
ELICIT-IDA




**Same circumstance tested un different C2 Approaches**

ELICIT-TRUST

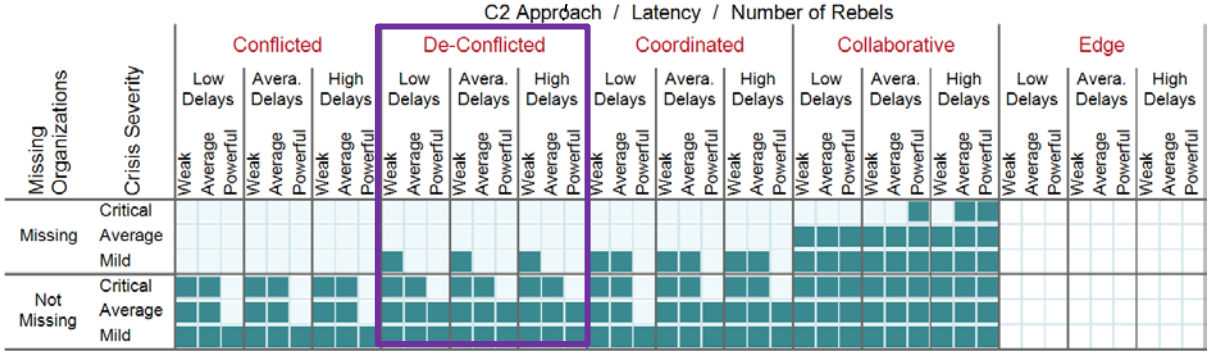


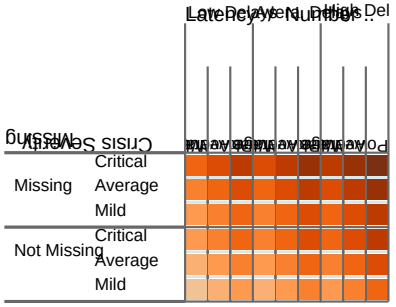

- Darker shades of teal correspond to higher levels of mission success (1), lighter ones to failure (0)
- Blank squares represent non-simulated cases

# More Network-Enabled = More Agility

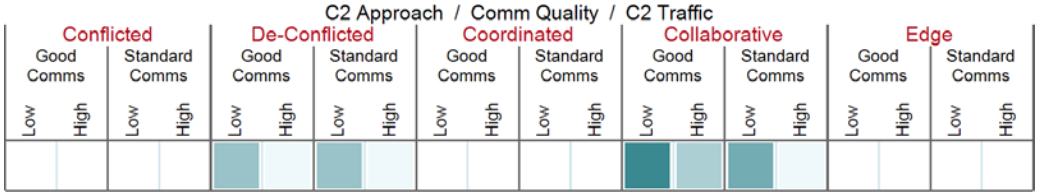
De-Conflicted was successful in 27 out of 54 circumstances
Agility Score (IMAGE, De-Conflicted) = 27/54 = 0.50

IMAGE

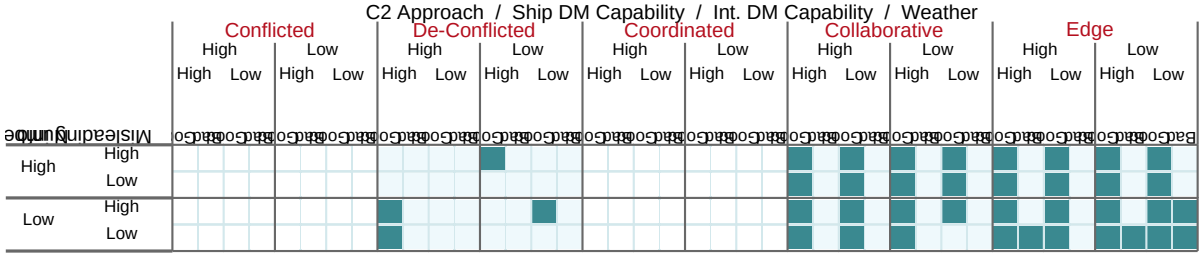


WISE



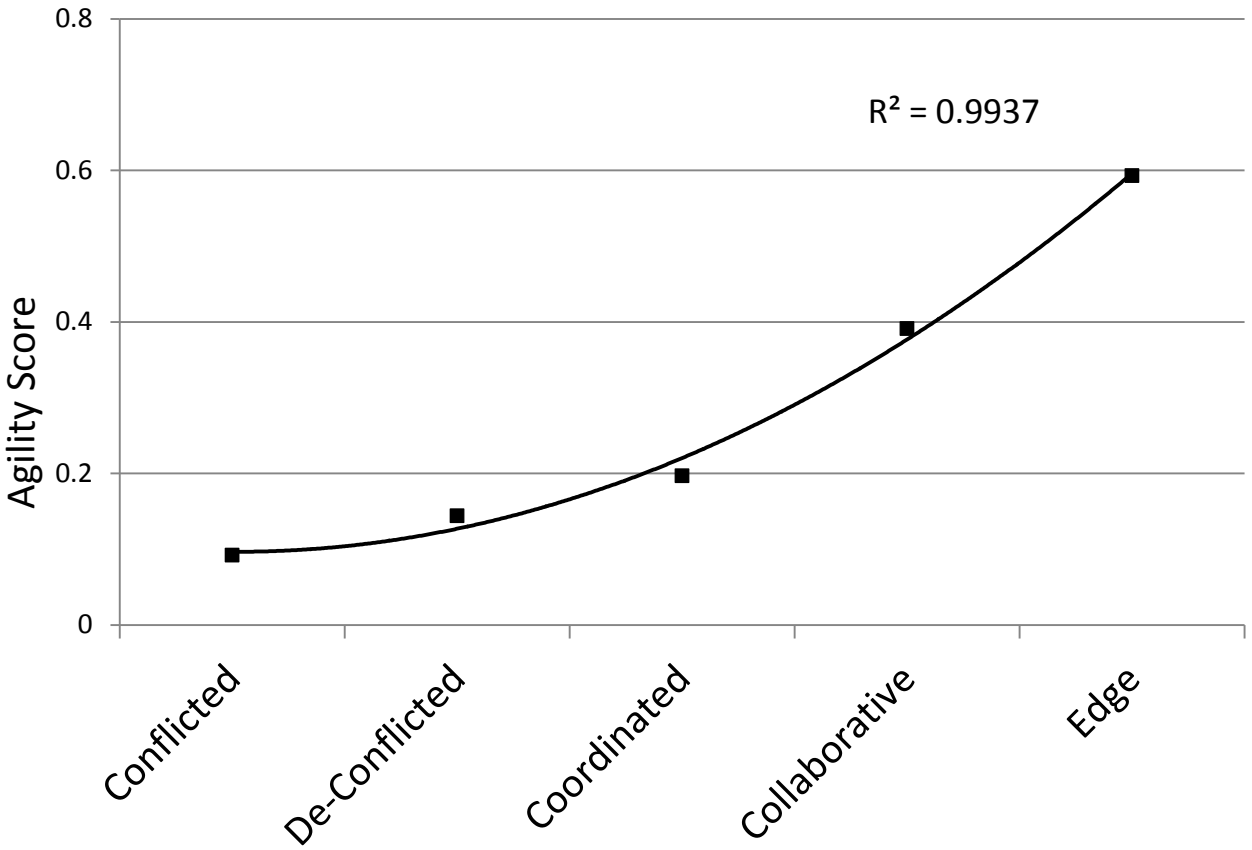

PANOPEA




- Darker shades of teal correspond to higher levels of mission success (1.0), lighter ones to failure (0.0)
- Blank squares represent non-simulated cases

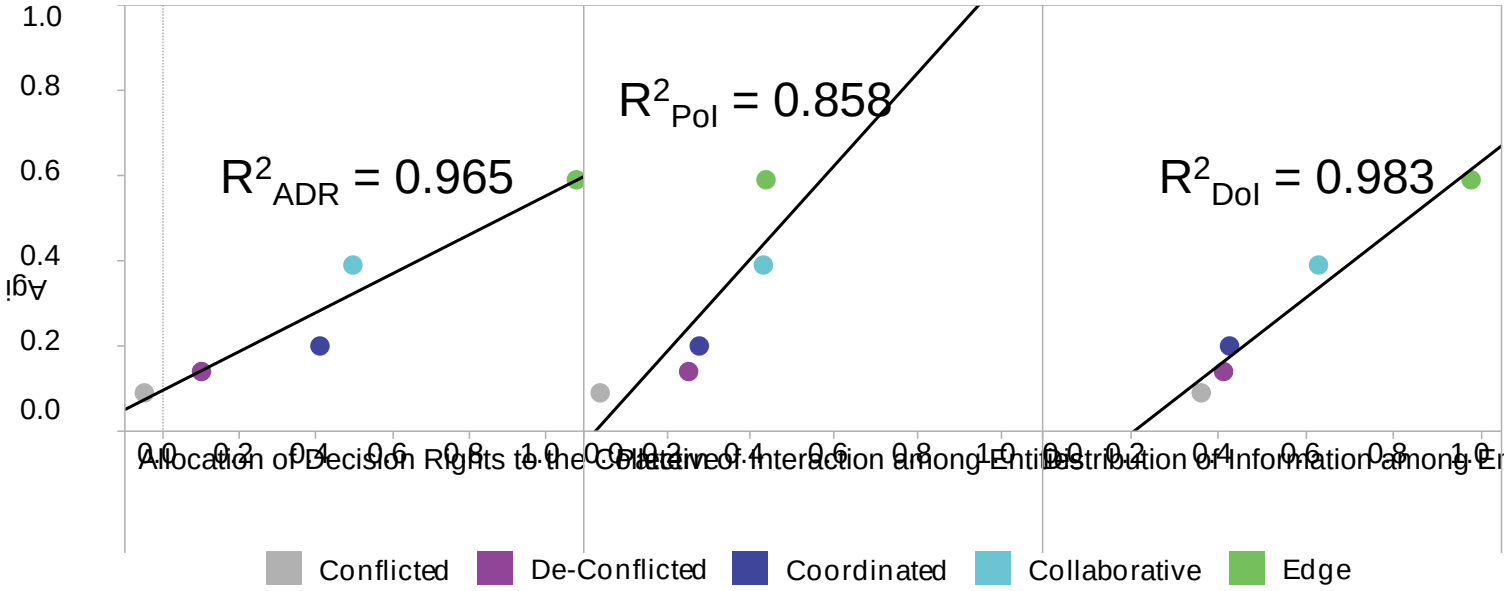
# More Network-Enabled = More Agility

- Results suggest that Agility accelerates as C2 approaches become more network-enabled
- The relation between C2 Approach and Agility Score is quadratic ($R^2 = 0.99$)



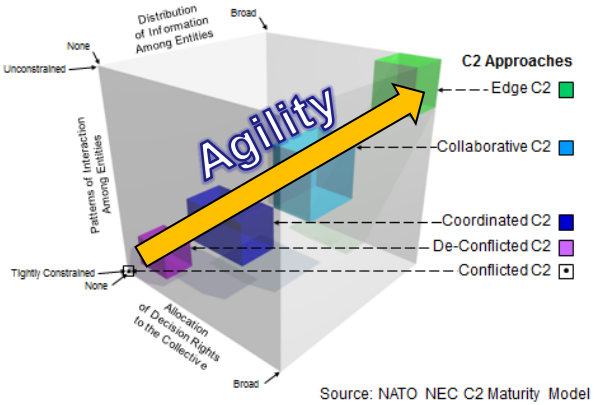
# C2 Approach Space → Agility

H5: The dimensions of the C2 Approach Space are positively correlated with agility




- Individually: Agility Score is strongly correlated to each dimension of the C2 Approach Space
- Collectively (multiple regression):

*Agility Score = 0.030 + 0.460 x Allocation of decision rights*
*– 0.269 x Patterns of interaction*
*+ 0.274 x Distribution of information*



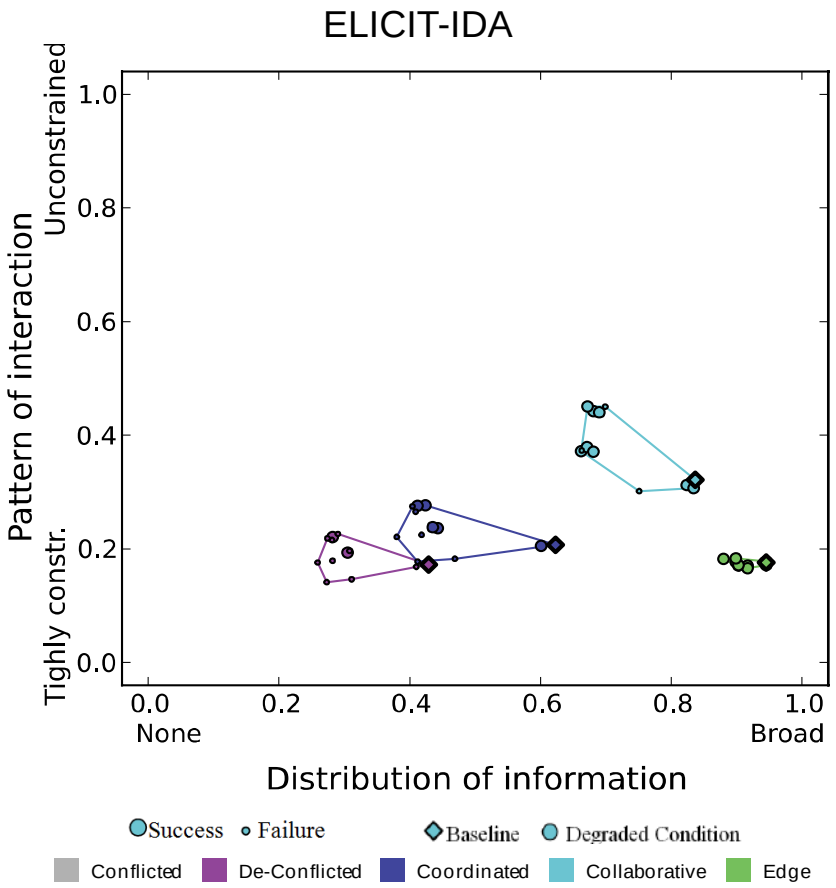

Source: NATO NEC C2 Maturity Model

# Location Variations in C2 Approach Space

H6: More network-enabled C2 approaches are better able to maintain their position in the C2 Approach Space

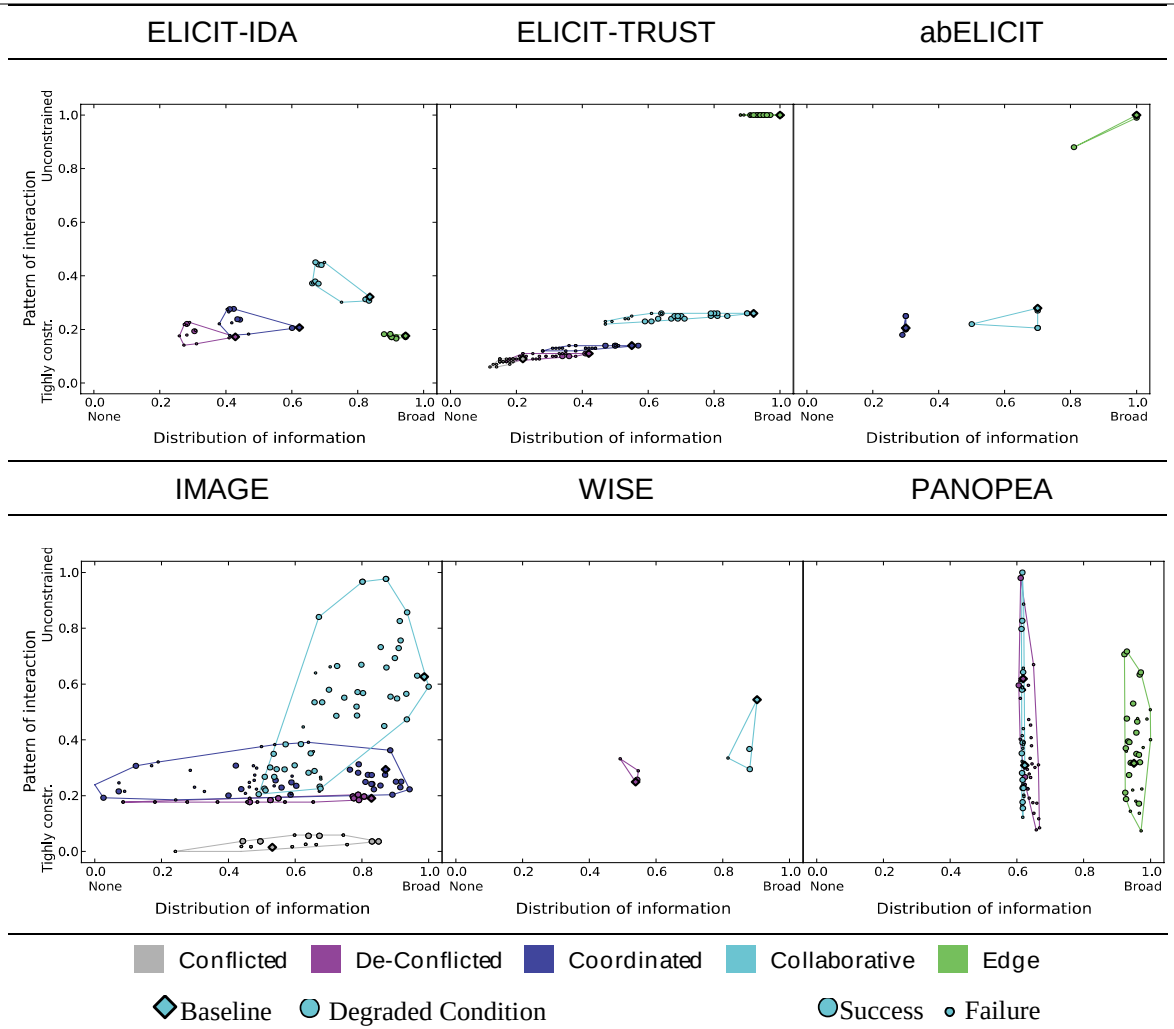
- Only patterns of interaction and distribution of information were affected by circumstances

- The deviation was measured by the spreading, calculated from the area occupied by all circumstances



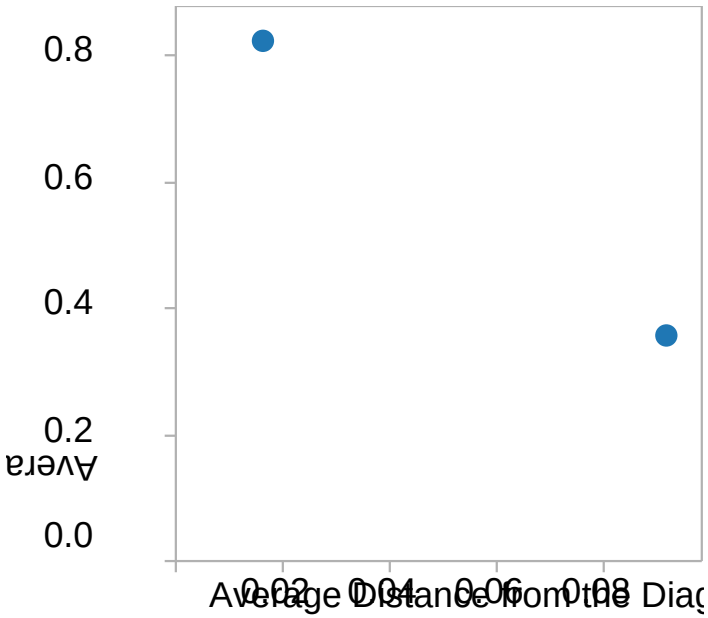
# Location Variations in C2 Approach Space

H6: More network-enabled C2 approaches are better able to maintain their position in the C2 Approach Space



# On vs. Off Diagonal

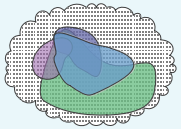
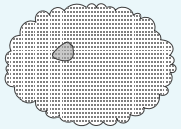
H7: On-diagonal (balanced) approaches to C2 are more agile




| C2 Approach | On-Diagonal Group | Off-Diagonal Group |
|---|---|---|
| Average % Maximum Effectiveness | 82% | 36% |
| Average Distance from Diagonal | 0.02 | 0.09 |

# C2 Maturity → C2 Agility

H9: More mature C2 capability is more agile than the most agile C2 Approach that can be adopted

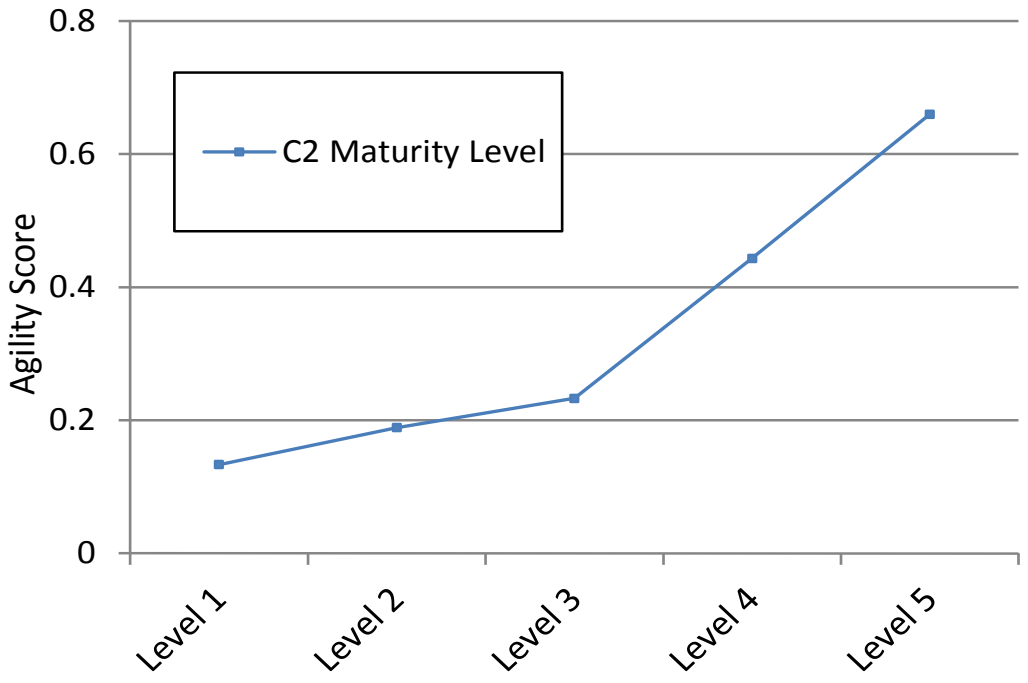
| C2 Maturity Levels | Contents of C2 Toolkit | C2 Approach Decision Requirement | Transition Requirements | Region of the Endeavor Space where a collective is successful |
|---|---|---|---|---|
| Level 5 | Edge C2<br>Collaborative C2<br>Coordinated C2<br>De-Conflicted C2 | Emergent | Edge C2<br>Collaborative C2<br>Coordinated C2<br>De-Conflicted C2 |  |
| Level 4 | Collaborative C2<br>Coordinated C2<br>De-Conflicted C2 | Recognize 3 situations and match to appropriate C2 approach | Collaborative C2<br>Coordinated C2<br>De-Conflicted C2 |  |
| Level 3 | Coordinated C2<br>De-Conflicted C2 | Recognize 2 situations and match to appropriate C2 approach | Coordinated C2<br>De-Conflicted C2 |  |
| Level 2 | De-Conflicted C2 | N/A | None |  |
| Level 1 | Conflicted C2 | N/A | None |  |

**Adapted from the Alberts, D.S. (2011). Agility Advantage, CCRP**

Conflicted De-Conflicted Coordinated Collaborative Edge

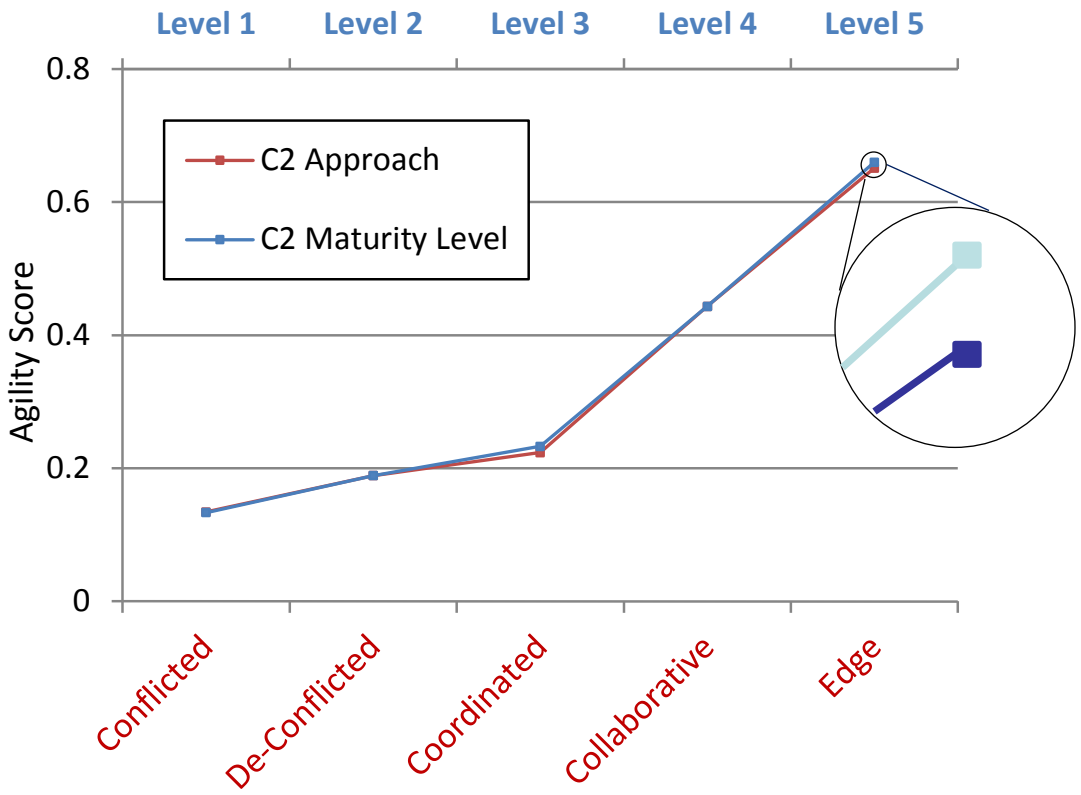
# C2 Maturity → C2 Agility

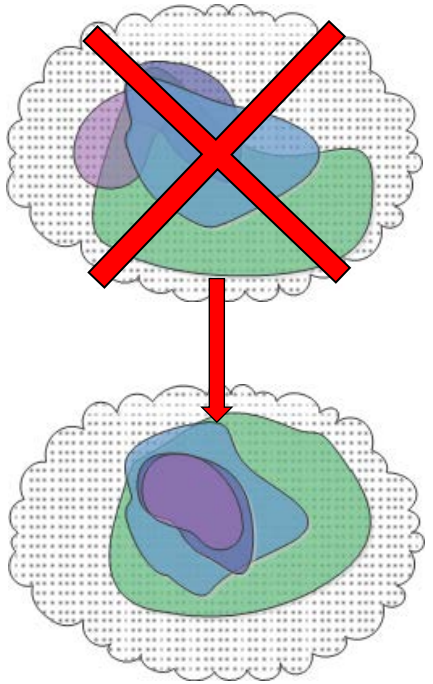
H9: More mature C2 capability is more agile than the most agile C2 Approach that can be adopted



# C2 Maturity → C2 Agility

***Experimental results suggest more an imbricated model than a complementary one***



# C2 Agility Experimentation

- DoD CCRP ELICIT
- SAS-085 Campaign of Experimentation (CAMPX)
- ARL Network Science Research Laboratory (NSRL)

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# C2 and its Constituent Networks

- A specific C2 Approach is defined in three dimensions
  - allocation of decision rights
  - patterns of interactions
  - distribution of information
- The allocation of decision rights is a design parameter of a social network that is a function of organizational structure
- A patterns of interaction is an outcome of a social network and is a function of prescribed or emergent organizational processes
- The distribution of information is a function of policies, processes, and individual propensities
- All of the above are enabled or constrained by capabilities provided by information and communications networks

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# C2 and Composite Networks

- A Composite Network is a collection of interdependent networks
- The values of each of the C2 Approach dimensions is the result of the outcomes associated with three interdependent networks (social, information, and communications), each with specific design parameters values, behaviors, and performance
- Thus, C2 experiments should be conceived of and instantiated as multi-genre composite network experiments

# Composite Network Experimentation

- Need to move beyond single genre experiments that represent the capabilities and performance of other networks by parameters
  - e.g. ELICIT will parameter determined communication delays
- ARL NSRL developed an ELICIT-EMANE* integrated environment as a first step in a planned development of a composite network experimentation environment
  - All interactions between social network nodes go through an emulated mobile tactical communications network
- This IOC capability will be enhanced with the introduction of an information network and network monitoring to explore integrated design of composite networks and context-aware network behaviors

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# Agenda

- C2 Agility
- Hypotheses
- Experiments and Results
- Next Steps

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# Frontiers of C2 Agility Research

- C2 of Composite Networks
- Cyber Security as a component of integrated design
- Automation and autonomy as a C2 Approach

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**12. DISTRIBUTION / AVAILABILITY STATEMENT**

Approved for public release; distribution is unlimited.

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**

The objective of this tutorial is to acquaint attendees with the foundational concepts upon which C2 Agility is constructed, the metrics that are associated with C2 Agility, and C2 Agility-related experimentation and results to date.

**15. SUBJECT TERMS**

C2, Agility, C2 Agility, Experimentation, Composite Networks

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| U | U | U | UU | 1 | 19b. TELEPHONE NUMBER (Include Area Code) (703) 845-2411 |